Radiation Data and Reports

VOLUME 14, NUMBER 10

OCTOBER 1973

(Pages 573–682)

RDDRA4 14(10) 573–682 (1973)

U.S. ENVIRONMENTAL PROTECTION AGENCY

Office of Radiation Programs

INTERNATIONAL NUMERICAL MULTIPLE AND SUBMULTIPLE PREFIXES

Multiples and submultiples	Prefixes	Symbols	Pronunciations
10^{12}	tera	T	tĕr'a
10^{9}	giga	G	jĭ'ga
10^{6}	mega	M	mĕg'a
10^{3}	kilo	k	kĭ'lo
10^{2}	hecto	h	hĕk'to
10	deka	da	dĕk'a
10^{-1}	deci	d	dĕs'i
10^{-2}	centi	c	sĕn'ti
10^{-3}	milli	m	mĭl'i
10^{-6}	micro	μ	mi'kro
10^{-9}	nano	n	năn'o
10^{-12}	pico	p	pē'ko
10^{-15}	femto	f	fĕm'to
10^{-18}	atto	a	ăt'to

SYMBOLS, UNITS, AND EQUIVALENTS

Symbol	Unit	Equivalent
Å	angstrom	10^{-10} meter
A	ampere(s)	
a	annum, year	
BeV	billion electron volts	GeV
Ci	curie	3.7×10^{10} dps-2.22×10^{12} dpm
cpm	counts per minute	
dpm	disintegrations per minute	
dps	disintegrations per second	
eV	electron volt	1.6×10^{-12} ergs
g	gram(s)	3.527×10^{-2} ounces= 2.205×10^{-3} pounds
Hz	hertz	cycle per second
kVp	kilovolt peak	
m	meter(s)	39.4 inches
m^3	cubic meter(s)	
mCi/mi^2	millicuries per square mile	0.386 nCi/m^2 (mCi/km^2)
mi	mile(s)	
ml	milliliter(s)	
nCi/m^2	nanocuries per square meter	2.59 mCi/mi^2
R	roentgen	
rad	unit of absorbed radiation dose	100 ergs/g
s	second	

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RADIATION DATA AND REPORTS

Volume 14, Number 10, October 1973

Radiation Data and Reports, a monthly publication of the Environmental Protection Agency presents data and reports provided by Federal, State, and foreign governmental agencies, and other cooperating organizations. Pertinent original data and interpretive manuscripts are invited from investigators.

In August 1959, the President directed the Secretary of Health, Education, and Welfare to intensify Departmental activities in the field of radiological health. The Department was assigned responsibility within the Executive Branch for the collation, analysis, and interpretation of data on environmental radiation levels. This responsibility was delegated to the Bureau of Radiological Health, Public Health Service. Pursuant to the Reorganization Plan No. 3 of 1970, effective December 2, 1970, this responsibility was transferred to the Radiation Office of the Environmental Protection Agency which was established by this reorganization.

The Federal agencies listed below appoint their representatives to a Board of Editorial Advisors. Members of the Board advise on general publications policy; secure appropriate data and manuscripts from their agencies; and review those contents which relate to the special functions of their agencies.

Department of Defense
Department of Agriculture
Department of Commerce
Department of Health, Education, and Welfare
Environmental Protection Agency
Atomic Energy Commission

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Address correspondence to the Editor, *Radiation Data and Reports*, Office of Radiation Program, Waterside Mall, E615, Washington, D.C. 20460.

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U.S. ENVIRONMENTAL PROTECTION AGENCY

Russell E. Train, Administrator

Reports

A History and Preliminary Inventory Report on the Kentucky Radioactive Waste Disposal Site[1]

David T. Clark[2]

The Kentucky radioactive waste disposal site, operated by the Nuclear Engineering Company, Incorporated, has been in operation since March 1963. As of January 1, 1972, approximately 0.71 million cubic meters of waste, containing 1,153,333 curies of byproduct material, 208,903 grams of special nuclear material, and 39,493 kilograms of source material, have been disposed of at this facility. Due to the relatively long period of operation and the large quantities of radioactive material involved, a detailed inventory of two of the largest pits at the site was made, based on available disposal records. This report contains a brief history of this facility and a summary of the inventory results.

In March of 1962, the State of Kentucky, through enabling legislation passed by the 1960 General Assembly, entered into agreement with the United States Atomic Energy Commission (AEC) to assume regulatory powers relating to the licensing of radioactive materials. In this agreement, authority was vested in the State to license the disposal of radioactive waste. The AEC retained authority to license the burial of high level waste resulting from the reprocessing of spent nuclear fuel.

With the primary intention of encouraging nuclear industry in Kentucky, the Kentucky Atomic Energy Authority pursued the concept of a radioactive waste disposal site in the State. Nuclear Engineering Company, Inc. (NECO), whose home office is in Walnut Creek, Calif., submitted an application to the Kentucky Department of Health for a license to bury radioactive waste at a proposed site in Fleming County, Ky. The Department of Health made an extensive and detailed review of the submitted application. Included in this detailed review was a comprehensive evaluation of the proposed site by the U.S. Geological Survey and the Kentucky State Geological Survey. Also assisting in this evaluation were the Oak Ridge National Laboratories, the U.S. Atomic Energy Commission, the U.S. Public Health Service (PHS), an independent geologist hired by the Nuclear Engineering Company, Inc., and a geological testing firm. The studies conducted by this evaluation team included geological, hydrological, and meteorological aspects. In addition, radiological studies were made of the natural radioactivity existing in the area in order to establish a baseline. It was concluded by this group that the site in Fleming County, known as Maxey Flats, located approximately 16 kilometers northwest of Morehead, was suitable for the disposal of solid radioactive waste.

As a result of this site approval based on the referenced evaluation, a license was issued for the disposal of solid byproduct, source, and special nuclear materials at the proposed site provided that the title of this site was conveyed to the Commonwealth in accordance with KRS 162.693 and Title 10 of the Code of Federal Regulations, Part 20.302.

In January 1963, a contract was negotiated between the Kentucky Atomic Energy Authority and the Nuclear Engineering Company, Inc., to operate a commercial radioactive waste disposal facility at the Maxey Flats site. This

[1] This project was made possible through a United States Environmental Protection Agency—Kentucky State Health Department contract.

[2] Radiological Health Program, Kentucky State Department of Health, 275 East Main Street, Frankfort, Ky. 40601.

site encompasses approximately 1.3 x $10^6 m^2$. The land originally was acquired by the Nuclear Engineering Company and the title to the land transferred to the State of Kentucky. The Kentucky Atomic Energy Authority, in turn, leased the tract of land to the Nuclear Engineering Company for a period of 25 years with the option to renew the lease for another 25-year period thereafter.

For the perpetual care of this site, the lease agreement contained a clause stating that the Nuclear Engineering Company would pay to the State of Kentucky a negotiated price per cubic foot of waste not to exceed 4 percent of the average burial charge per cubic foot charged by the licensee.

Under the conditions of the original license issued October 22, 1962, the licensee was restricted to the following possession limits for unburied radioactive material: (1) 400 curies of byproduct material; (2) 350 grams of special nuclear material; and (3) 907 kilograms of source material.

Through amendments to the original licenses over the years, the present license imposes the following limits.

License condition 8

The licensee shall not receive and possess at any one time unburied radioactive material in excess of:

(a) 5,000 curies of radioactive material excluding source and special nuclear materials;
(b) 4,500 kilograms of source materials;
(c) 350 grams of uranium-235, 200 grams of uranium-233, 200 grams of plutonium; or any combination of them in accordance with the following formula: for each kind of special nuclear material, determine the ratio between the quantity of that special nuclear material and the quantity specified above for the same kind of special nuclear material. The sum of such ratios for all kinds of special nuclear material in combination shall not exceed unity; and
(d) the licensee shall not receive or possess at any one time a quantity of radioactive material in excess of that specified in Paragraph 8.a., unless the agency has first evaluated the proposed packaging, handling and burial procedures, determined that the proposed operations can be accomplished without undue risk to the health and safety of occupationally exposed individuals and the public, and issued an authorization letter.

The provisions of condition 8.d. have been used numerous times by the company (appendix 1).

Even though the above restrictions are imposed on the amount of material that can be received per shipment and/or stored at Maxey Flats, the types of radioactive material as well as the total quantity that may be buried are essentially unlimited. Most of the solid wastes are buried in rectangular trenches approximately 110 meters long, 21 meters wide, and 6 meters deep. Initially, these trenches were described as being approximately 76 meters long, 6 meters wide and 6 meters deep. Through December 1971, there have been 23 of these trenches constructed and filled (appendix 2). The floor of the trench is to have a slope of approximately 1 degree to a sump and stand pipe positioned at the lowest level. Gravel drains were initially required but discontinued when it was considered that random dumping provided adequate voids for migration of infiltrants to the sumps. Most wastes are randomly dumped in the pit beginning at the high end and backfilling as required to reduce radiation levels. The radiation level at the surface of the earth above the completed pits is not allowed to exceed 2 mR/h. Levels around the open pits are not allowed to exceed 100 mR/h.

Each completed trench is required to be backfilled with a minimum of 1 meter of earth materials mounded and compacted to form and maintain an "umbrella" to seal out ground water to the greatest extent possible and to divert rain water away from the trench. Following settling, a shallow rooted crop is to be planted to prevent erosion.

Finally, a monument is placed at the end of each pit and inscribed with the number of the pit and date of closure. This is to provide a reference to the records (appendix 3), which contain the following additional required information:

(a) location and definition of trench boundary;
(b) total activities of radioactive material in curies excluding source and special nuclear materials, total amount of source material in kilograms, and total amount of special nuclear material in grams in the trench;
(c) radionuclides with greatest hazard potential;
(d) date of completion of the burial operation; and
(e) volume of waste in trench.

During most of the use of this facility, the bulk of the liquids have been solidified using cement and newspaper. The concrete and paper mixture was buried in trenches lined with polyethylene. When the trench was filled, the polyethylene was lapped over the top and capped as previously described. The solidified liquids have been buried in separate pits of which 11 have been constructed and filled as of the end of 1971. As of January 1, 1972, NECO had solidified and disposed of 2,243,230 liters of liquid radioactive waste. As can be seen from the table in appendix 4, there had been no significant increase in amounts of liquids disposed until 1971, when 1,286,660 liters were disposed of at this site. This dramatic increase in disposal rates is attributable almost solely to the nuclear power reactor industry and is due to the present philosophy of "Zero Release."

Generally, high specific gamma activity sources are not buried in the large trenches since they would create an exposure problem for personnel during dumping and filling operations. These wastes, if sufficiently small in size, are deposited in special hot wells constructed about 4.6 meters deep with pipes of coated steel, concrete, or tile placed vertically in the ground and closed at the lower end and capped at the upper end. When the number of sources or the radiation level renders it inappropriate to place additional materials in the pipe, the pipe is filled with concrete. There are eight such wells on site and seven have been sealed.

Other high intensity sources of larger volume, such as resins from reactor facilities, are placed in individual pits approximately 9 meters long by 3 meters wide by 3 meters deep. A sump pipe is placed in each of the pits for monitoring and water removal.

The first radioactive material was buried at this site in May 1963. Early preliminary estimates were based on an assumed burial rate of waste at this site of approximately 750 curies per year. It soon became evident that this was a gross underestimation, for in 1963, 2,206.0 cubic meters of waste containing 22,556 curies of byproduct material were disposed of at this site. As of January 1, 1972, approximately 0.71 million cubic meters containing 1,153,333 curies of byproduct material, 208,903 grams of special nuclear material and 39,493 kilograms of source material have been disposed of at this site. The annual and cumulative rates are shown graphically in appendix 5. The cumulative volume of material buried has increased almost exponentially, with the amount of special nuclear material buried doubling approximately every 1.3 years.

There is no specific exclusion of hazardous toxic materials at this time, provided that they are in association with potentially hazardous radioactive materials. However, on October 16, 1970, the Nuclear Engineering Company, Inc., was notified that a request by them, dated September 16, 1970, for a solid waste disposal permit for the disposal of nonradioactive, hazardous, toxic or dangerous wastes at their site at Maxey Flats would not be issued. The Solid Waste Program and the Division of Environmental Health, in a joint meeting, had determined that the granting of such a permit would not be in the best public interest.

At this time, no provision has been made to document chemical form or type of material; however, the following interim policy was adopted on June 2, 1972 by the Kentucky Radiological Health Program regarding the burial of radioactive material in combination with chemically toxic waste:

> "When waste contains both radioactive materials and toxic chemicals, the potential hazard of both will be evaluated independently. The waste containing both radioactive material and chemical toxic waste will

not be accepted for burial at the Kentucky radioactive waste disposal site, if the chemical hazard exceeds the radiological hazard. The determination of the hazard will be performed by the Radiological Health staff after consultation with toxic chemical experts. As a guide in making this evaluation, any toxic chemical falling in Category 3 listed in the manual "Dangerous Properties of Industrial Materials," 1968, by Irving Sax, shall be considered more hazardous than its associated radioactive material, until it is determined by the staff that this is not the case."

This policy was adopted as an interim policy only. It is strongly recommended that this problem be better defined by experts in the field of radiation safety, solid waste management, toxic chemical experts, and other appropriate persons knowledgeable of the problems involved. It is further recommended that a national position be established for all radioactive waste disposal sites throughout the United States.

The disposal records maintained by NECO include the following information:

(1) the date of receipt;
(2) the physical state (solid, liquid, or gas);
(3) the principal radioisotope;
(4) the activity; and
(5) the customer.

The company is also able to identify the pit and approximate location where each shipment is buried.

Due to the relatively long period of operation and large quantities of radioactive materials disposed of at this site, the Kentucky Radiological Health staff initiated a study to determine the current inventory of specific radioactive materials at the Kentucky NECO waste disposal site. Prior to June 1970, all radioactive shipment records (RSR) had been filed according to customer's name with a separate file maintained to indicate pit placement. After this date, all RSR's have had the pit into which the shipment was placed noted on them and filed by pit number. With this information it was decided to first compile an inventory of the two pits completed since this policy went into effect.

The first pit inventory to be completed was for pit no. 30. This pit was opened in June 1970 and closed February 1971. According to the monthly burial reports submitted by the licensee to the Agency, pit no. 30 contained 23,940 curies of byproduct material, 48,713 grams of special nuclear material, and 6,471.9 kilograms of source material. The total combined volume of all radioactive waste buried in pit no. 30 was 8,984.41 cubic meters.

For the purpose of analyzing the byproduct material components within the pits, the staff arbitrarily chose five specific nuclides for identification. These nuclides included cesium-137, strontium-90, cobalt-60, tritium, and radium-226. They were chosen because of their significant biological effect and relatively long half-lives. The total activity for each chosen nuclide and the percent of the total buried activity in pit no. 30 is shown in table 1.

Table 1. Radioactivity of selected nuclides buried in pit no. 30, Maxey Flats

Radionuclide	Activity[a] (curies)	Percent of total by-product activity
Cesium-137	343.96	1.4
Strontium-90	988.47	4.1
Cobalt-60	7,218.66	30.2
Tritium	414.7	1.7
Radium-226	.292	<1

[a] Initial activities—activities as recorded on the original shipment forms.

In addition to the identification by the five referenced specific nuclides, a second broad category was identified. This category is defined as mixed fission products (MFP). This category includes items identified on the shipping records specifically as mixed fission products, and additionally, includes items shown on the shipping records for which only one activity is shown for a multiradionuclide combination. An example of the latter case is: iodine-131, tritium, and zinc-65 - 10 mCi.

Probably the most significant finding of this study is the amount of MFP buried at this site. The records indicate that 10,329.91 curies of MFP were buried in pit no. 30. This represents 43.2 percent of the total byproduct material in the pit.

The remaining 19.4 percent of 4,644 curies of byproduct material in pit no. 30 is made up of very short half-life material received from

academic and medical institutions (technetium-99m, iodine-131, etc.).

In addition to an analysis of the byproduct material, a determination was made of the plutonium-239 buried as special nuclear material. Of the total 48,713 grams of special nuclear material in pit no. 30, 2,155.48 grams were identified as plutonium-239.

The effective half-life for the byproduct material contained in pit no. 30 was calculated. This calculation was based on the half-lives of the five identified radionuclides and an estimated half-life of 1.6 years for mixed fission products. For a discussion of the calculation of the effective byproduct half-life for pit no. 30, see appendix 6.

The special nuclear material and source material buried in this pit were not included in the calculation. It is obvious that the effective half-life, if special nuclear material and source material were included, would be in the thousands of years. From a public health consideration, one would consider plutonium-239 as being the most hazardous material in this category, and therefore a half-life for special nuclear material and source material could be assigned as 24,390 years.

The second pit inventory that was completed was pit no. 32, which was opened in September 1971 and closed in May 1972. According to the monthly burial records submitted by the licensee to the agency, pit no. 32 contained 28,310 curies of byproduct material, 54,327 grams of special nuclear material, and 9,436.5 kilograms of source material. The total combined volume of all radioactive waste buried in pit no. 32 was 8,436.65 cubic meters.

The specific byproduct material identification in pit no. 32 is shown in table 2.

In addition to the above five nuclides, the amount of byproduct material identified as MFP in pit no. 32 was 13,618 curies representing 48 percent of the total byproduct material in the pit.

The remaining 25.5 percent or 7,219 curies of byproduct material is made up of short half-life nuclides.

For pit no. 32, of the total 54,327 grams of special nuclear material, 12,966 grams of plutonium-239 were identified.

Table 2. Specific byproduct material identification in pit no. 32, Maxey Flats

Radionuclide	Activity (curies)	Percent of total byproduct activity
Cesium-137	299.18	1
Strontium-90	562.0	2
Cobalt-60	4,673.0	16.5
Tritium	2,063.0	7
Radium-226	8.0	<1

The byproduct half-life for pit no. 32 was also calculated (appendix 7).

During the course of this inventory study, we have accumulated additional information on seven other pits. As can be seen by the tabulation in appendixes 8 and 9, this information is not complete and will require much additional time to complete.

The tabulation in appendix 9 is only a partial listing of company inventories. A complete listing will be completed in the future. The following paragraphs contain a summary of some of the information resulting from the study so far.

Company I is a major contributor to the large quantities of special nuclear material disposed of at this site. Our study of the records show that this company through December 14, 1971 disposed of 90,299 grams of special nuclear material, and 3,086 grams of plutonium-239.

Company J, as of September 28, 1971, had shipped for disposal to the Nuclear Engineering Company, 140,282 curies of radioactive byproduct material. Of this quantity, 122,418 curies was not identifiable as to specific isotopes. The record showed that most of their waste was listed as mixed fission products (appendix 11).

Many irregularities were encountered in the course of this study. We have found that the Nuclear Engineering Company has accepted shipments where the RSR's included activity or isotopic designations that the company did not understand. (Examples: Plutonium-238 in UCC, D-38 Tuballoy oxide, etc.). There were several RSR's encountered in this study which would indicate that the Nuclear Engineering Company, Inc., had received and disposed of nonradioactive chemical waste at the Kentucky waste disposal site.

Recommendations

This pilot inventory has shown the need for an improved record-keeping system for the accountability of radioactive waste. The information obtained during this study has shown a definite need to continue a complete inventory of the Kentucky radioactive waste disposal site. Therefore, the first recommendation is that efforts be made to continue the inventory study of the Kentucky site.

As a result of this pilot study, the following specific recommendations are made to improve the records system for the accountability of radioactive waste.

(1) All burial records should be on a form which can be handled by automatic data processing equipment.

(2) All commercial waste disposal facilities should adopt a uniform format for disposal of waste.

(3) The format for collecting the data should include the following:
   (a) The specific radionuclide.
   (b) The activity in curies for byproduct material and naturally occurring or artificially produced materials.
   (c) The weight of special nuclear material in grams and specifically, the plutonium-239 in grams.
   (d) The weight of source material in kilograms.
   (e) The chemical composition of each shipment. The identification of the chemical composition normally specifies the elemental composition. This should be done when possible; however, with some shipments, e.g. carcasses, it is impossib'e to identify the elemental composition, such as a carcass. For shipments in which the elemental composition cannot be identified, the shipper should identify the shipment by the name of the item being shipped.
   (f) The most chemically toxic material associated with the radioactive waste and the concentration of this toxic material.

(4) A requirement by the licensing agency of the disposal facility that the shipment be rejected, if the shipper has not identified the waste as described above.

(5) Regulatory agencies should inspect more closely the records of disposal of each licensee for compliance with their regulations on waste disposal record-keeping.

Much of the data in this report was taken from an unpublished report by Joel G. Veater, EPA Region IV (Atlanta, Ga.) and David T. Clark, Kentucky State Department of Health, Frankfort, Ky.

APPENDICES

Appendix 1. Special authorizations for burials exceeding the limits of the Kentucky waste disposal license

Date	Material buried	Radioactivity (curies)
June 26, 1972	Mixed fission products	20,613
April 27, 1972	Irradiated steel tube and control rod	17,000
April 19, 1971	Tritium	645,400
February 25, 1971	Cobalt-60	31,867
November 15, 1966	Cobalt-60	20,000

APPENDIX 2

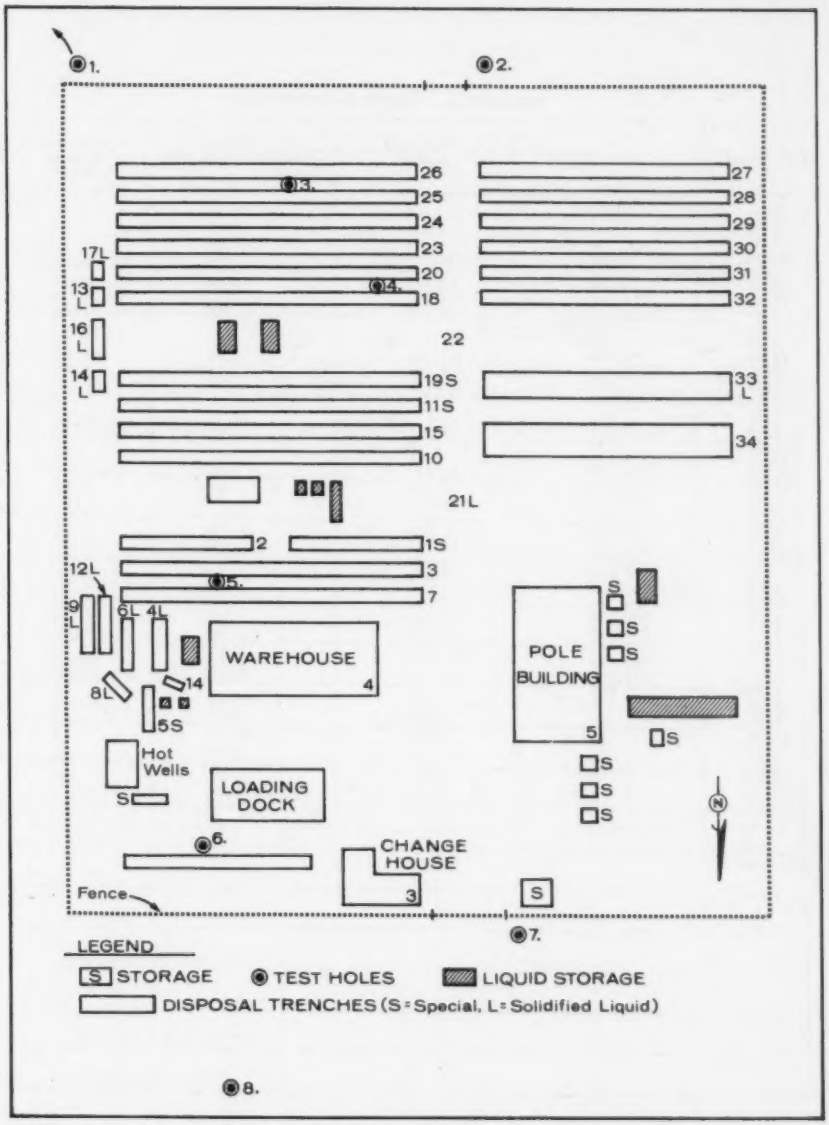

Figure 1. Sketch of Maxey Flats radioactive waste disposal facility

APPENDIX 2

Appendix 2. Specific pit information

Pit number[a]	Date closed	Cubic feet	Byproduct (curies)	Curies per cubic foot	Special nuclear material (grams)	Source material (pounds)
1	5/63	16,307	409	0.025	28	651
1s	10/63	3.752	2,254		1	0
2	7/63	18.073	82	4.54	59	15
3	10/63	24,409	11,343	.46	435	10,737
4	10/63	749	0		0	0
5s	4/64	7,015	13,173	1.88	405	5
6L	11/63	603	11	.018	0	3
7	4/64	34,722	24,490	.705	1,614	1,130
8L	1/64	2.246	.05		0	0
9L	3/64	1,520	.02		0	0
10	12/64	82,227	107,762	1.31	8,083	11,070
11	9/65	62,630	9,834	.157	2,566	1,064
12L	7/64	839	1		0	0
13L	9/64	749	.01		0	0
14L	6/66	400	.05		0	0
15	9/65	92,793	41,829	.45	1,628	188
16L	4/65	709	8		0	0
17L	12/65	3,613	14		0	0
18	2/66	66,149	15,116	.228	1,830	12
19s	12/66	93,110	27,314	.293	3,834	495
20	11/66	96,629	24,201	.25	3,198	1,016
21L	10/71	22,780	132		2,240	640
22	1/72	1,689	35,122	20.794	8	0
23	6/67	113,178	18,533	.163	4,957	2,283
24	10/67	92,670	4,563	.049	1,598	297
25	1/68	71,103	8,271	.116	5,169	4,282
26	5/68	91,038	14,437	.158	5,917	689
27	2/69	224,334	22,591	.10	11,638	12,904
28	9/69	209,898	11,719	.055	21,473	5,335
29	6/70	270,746	27,513	.10	13,427	1,890
30	2/71	317,282	23,940	.07	48,713	14,268
31	10/71	280,549	666,344	2.36	46,476	2,208
32	5/72	297,938	28,310	.095	54,327	20,804
33L	1/72	27,950	43		0	0
HW1	1/64	8	4,661	582.63	0	0
HW2	4/66	29	1,289	44.45	0	0
HW3	11/66	37.5	1,224	32.64	0	0
HW4	10/67	12	17	1.42	0	0
HW5	2/68	40	602	15.05	285	0
HW6	5/68	71	784	11.04	346	0
HW7	12/70	9.35	1,971	210.80	0	0
HW8	3/71	14.8	249,310	16,845.27	0	0

[a] s-special pit.
L-solidified liquid waste pit.
HW-hot well.

APPENDIX 3

NUCLEAR ENGINEERING COMPANY, INC.

Kentucky FACILITY

REPORT OF RECEIPT AND BURIAL OF RADIOACTIVE WASTE MATERIALS:

MONTH August 1972 BY B. V. Roberts, Vice President

PIT NO.		CUBIC FEET	BYPRODUCT (curies)	S.N.M. (grams)	SOURCE (pounds)
34	BURIED THIS MONTH:	599.70	69,312.00	138.00	0.00
	BURIED TO DATE:	1,988.60	97,624.35	491.00	0.00
35	BURIED THIS MONTH:	46,013.86	20,847.81	3,562.27	0.00
	BURIED TO DATE:	181,466.52	39,283.78	17,960.10	3,459.70
	BURIED THIS MONTH				
	BURIED TO DATE:				
	BURIED THIS MONTH:				
	BURIED TO DATE:				
	BURIED THIS MONTH:				
	BURIED TO DATE:				
	BURIED THIS MONTH:				
	BURIED TO DATE:				

TOTAL:

	BURIED THIS MONTH:	46,613.56	90,159.81	3,700.27	0.00
	BURIED TO DATE:	2,831,226.61	1,313,601.40	263,188.48	100,896.90

SNM, special nuclear material

STORAGE:	0.00			
GALLONS: (173,847)	23,116.33	104.69	0.00	0.00

Figure 2. Report of receipt and burial of radioactive waste materials

APPENDIX 4

Appendix 4. Disposal of solidified liquid radioactive waste material at the Nuclear Engineering Company facility

Year	Yearly rate (gallons per year)	Cumulative total (gallons per year)
1963	18,514	
1964	31,624	50,138
1965	32,325	82,463
1966	22,047	104,510
1967	30,590	135,100
1968	55,497	190,597
1969	44,762	235,359
1970	20,009	255,368
1971	339,936	595,304

APPENDIX 5

Appendix 5. Nuclear Engineering Company burial rates

Year	Cubic feet	Byproduct (curies)	Curies per cubic foot	Special nuclear material (grams)	Source material (pounds)
1963	77,905	22,556	0.29	959	11,487
1964	136,736	147,218	1.1	11,770	12,333
Cumulative total	214,641	169,774		12,729	23,820
1965	203,129	63,828	.31	4,261	1,252
Cumulative total	417,770	233,602		16,090	25,072
1966	196,205	52,737	.27	7,462	1,521
Cumulative total	613,975	286,339		24,452	26,593
1967	276,158	23,272	.08	14,842	12,516
Cumulative total	890,133	309,611		39,294	39,109
1968	288,757	45,578	.16	17,771	13,772
Cumulative total	1,178,890	355,189		57,065	52,881
1969	365,596	31,028	.09	31,506	5,631
Cumulative total	1,544,486	386,217		88,571	58,512
1970	442,128	56,969	.13	47,562	15,913
Cumulative total	1,986,615	443,186		136,133	74,425
1971	465,145	710,147	* .14	72,770	12,643
Cumulative total	2,451,759	1,153,333		208,903	87,068

* This figure does not include a single shipment of 645,000 curies of tritium.

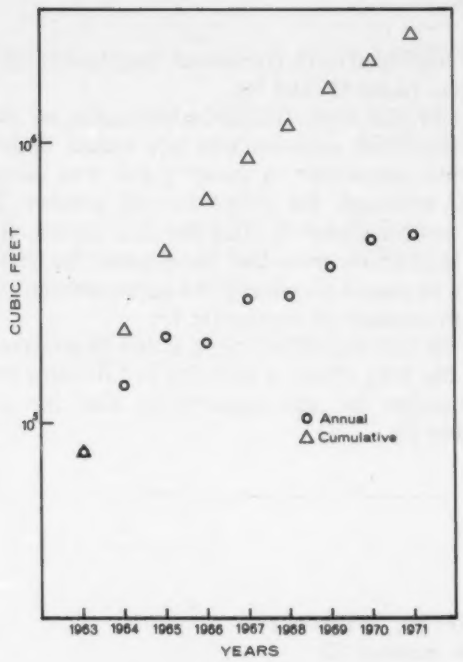

Figure 3. Burial of radioactive waste material (cubic feet per year)

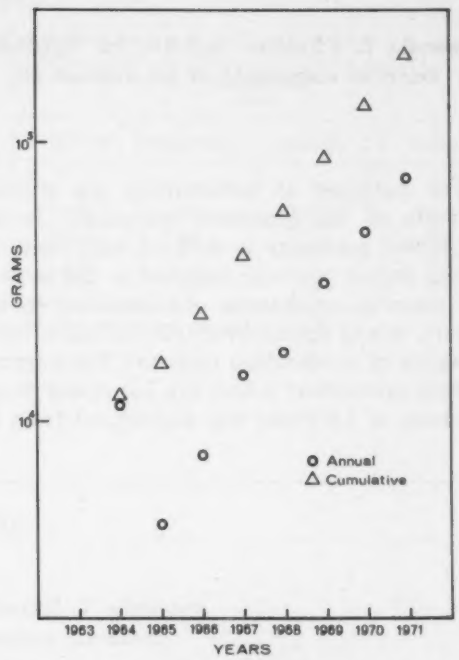

Figure 4. Burial of radioactive waste special nuclear material

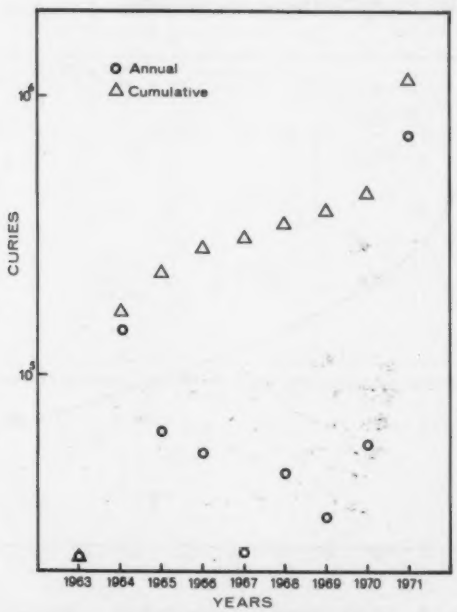

Figure 5. Byproduct material

APPENDIX 6

Appendix 6. Effective half-life for byproduct material component of pit number 30

For purposes of determining the effective half-life of the byproduct component in this pit, it was necessary to assign a half-life to the mixed fission products included in the byproduct material component. As indicated in this report, mixed fission products include a broad category of unidentified material. For purposes of this calculation, a half-life for mixed fission products of 1.6 years was determined from the *Radiological Health Handbook*, September 1960 edition, pages 98 and 99.

Using the activity-time relationship of the five identified nuclides and the mixed fission product component, a decay curve was calculated. Although the curve for pit number 30 was not completed in time for this report, the first indications were that the slope of the curve followed almost identically the curve determined for pit number 32 (appendix 7).

From this calculated curve, it can be observed that the first effective half-life is 2.6 years for pit number 32, and apparently, also for pit number 30.

APPENDIX 7

Appendix 7. Effective half-life for byproduct material component of pit number 32

The calculated effective half-life curve for the byproduct component in pit number 32 is shown below. The calculated curve for pit 32 and pit 30 appeared to be identical.

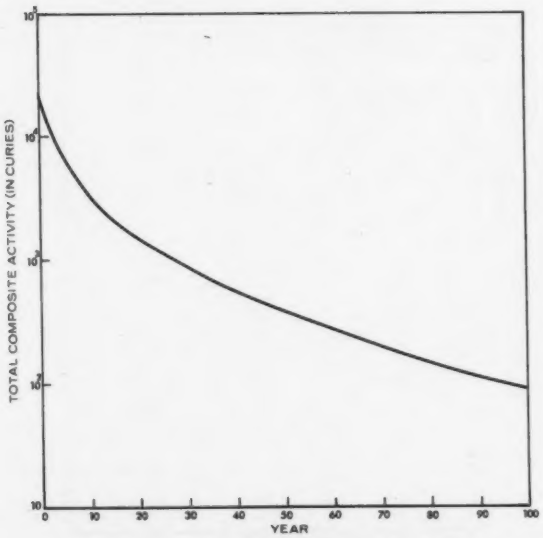

Figure 6. Curve showing activity-time relationship of total composition activity buried in pit number 32

APPENDIX 8

Appendix 8. Summary of pit inventories

Pit number	Not specifically identifiable [a] (curies)	Special nuclear material (grams)	Plutonium-239 (grams)	Radioactivity (curies)			
				Cobalt-60	Strontium-90	Radium-226	Tritium
21L [b]	5.943						
22	154.141			78.8			
30 [c]	14,606.286	47,114.33	1,730.36	4,554	115.1	6.339	794.6
31	3,824.933	5,836.92	829.26	1,734		10.935	42.7
32 [c]	13,618.395	53,753.94	12,966.29	4,673	562.9	58.003	2,062.7
33L [b]	3.457			3.7			31.2
34	23,805.866			1,200			
35	362.227	3,168.20	508.41	1,923	2.5	.021	15.75

[a] This group includes mixed fission products and listings that had more than one radioisotope associated with a given activity.
[b] L-solidified liquid waste pit.
[c] Completed inventory.

APPENDIX 9

Appendix 9. Summary of completed company inventories

Company	Not specifically identifiable [a] (curies)	Special nuclear material (grams)	Plutonium-239 (grams)	Radioactivity (curies)			
				Cobalt-60	Strontium-90	Radium-226	Tritium
A	74.083	0.10		95,259	40.2	0.056	57.7
B	1.290						51.5
C	4.154						
D	569.249			1,977		.02	205.7
E	.094	1,536.7		.70		.01	
F	.480						
G	3,885.874			987		.074	41.24
H	614.415			19,727	2.0		4.0
I	64.025	90,299.23	3,086.08	11.4	.67		
J	122,418.375	246.45	17,618.45	3,010			
K	347.055	6,679.58		1.5			19.0
L	.410						
M	.030					.010	
N	2,027.330			9.1			32.6

[a] This group includes mixed fission products and listings that had more than one radioisotope associated with a given activity.

SECTION I. MILK AND FOOD

Milk Surveillance, June 1973

Although milk is only one of the sources of dietary intake of environmental radioactivity, it is the food item that is most useful as an indicator of the general population's intake of radionuclide contaminants resulting from environmental releases. Fresh milk is consumed by a large segment of the population and contains several of the biologically important radionuclides that may be released to the environment from nuclear activities. In addition, milk is produced and consumed on a regular basis, is convenient to handle and analyze, and samples representative of general population consumption can be readily obtained. Therefore, milk sampling networks have been found to be an effective mechanism for obtaining information on current radionuclide concentrations and long-term trends. From such information, public health agencies can determine the need for further investigation or corrective public health action.

The Pasteurized Milk Network (PMN) sponsored by the Office of Radiation Programs, Environmental Protection Agency, and the Office of Food Sanitation, Food and Drug Administration, Public Health Service, consists of 63 sampling stations: 61 located in the United States, one in Puerto Rico, and one in the Canal Zone. Many of the State health departments also conduct local milk surveillance programs which provide more comprehensive coverage within the individual State. Data from 15 of these State networks are reported routinely in *Radiation Data and Reports*. Additional networks for the routine surveillance of radioactivity in milk in the Western Hemisphere and their sponsoring organizations are:

Pan American Milk Sampling Program (Pan American Health Organization and U.S. Environmental Protection Agency)—7 sampling stations

Canadian Milk Network (Radiation Protection Division, Canadian Department of National Health and Welfare)—16 sampling stations

The sampling locations that make up the networks presently reporting in *Radiation Data and Reports* are shown in figure 1. Based on the similar purpose for these sampling activities, the present format integrates the complementary data that are routinely obtained by these several milk networks.

Radionuclide and element coverage

Considerable experience has established that relatively few of the many radionuclides that are formed as a result of nuclear fission become incorporated in milk (*1*). Most of the possible radiocontaminants are eliminated by the selective metabolism of the cow, which restricts gastrointestinal uptake and secretion into the milk. The five fission-product radionuclides which commonly occur in milk are strontium-89, strontium-90, iodine-131, cesium-137, and barium-140. A sixth radionuclide, potassium-40, occurs naturally in 0.0118 percent (*2*) abundance of the element potassium, resulting in a specific activity for potassium-40 of 830 pCi/g total potassium.

Two stable elements which are found in milk, calcium and potassium, have been used as a means for assessing the biological behavior of metabolically similar radionuclides (radio-

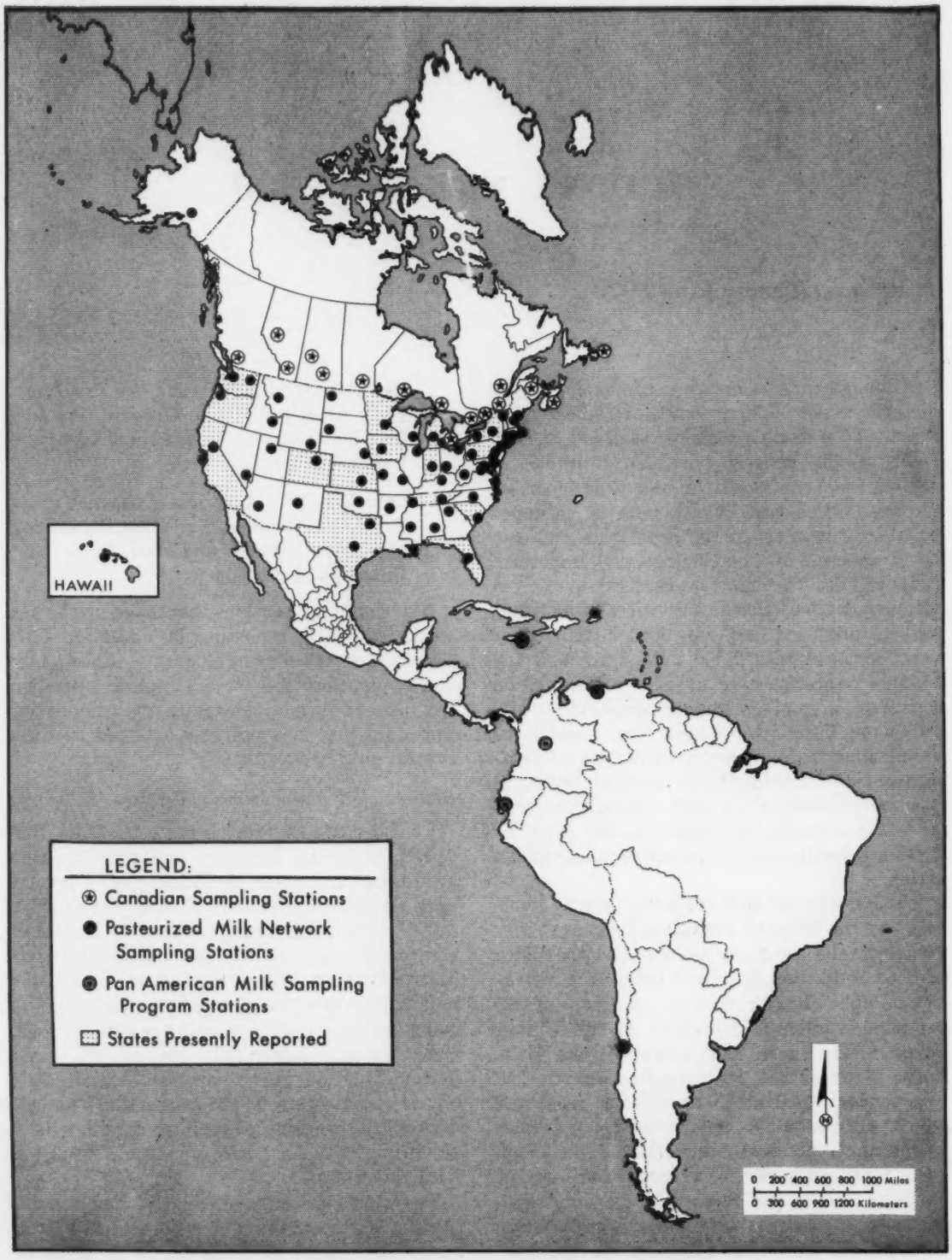

Figure 1. Milk sampling networks in the Western Hemisphere

strontium and radiocesium, respectively). The contents of both calcium and potassium in milk have been measured extensively and are relatively constant. Appropriate values and their variations, expressed in terms of 2 standard deviations (2σ), for these elements are 1.16 ± 0.08 g/liter for calcium and 1.51 ± 0.21 g/liter for potassium. These figures are averages of data from the PMN for May 1963–March 1966 (*3*) and are used for general radiation calculations.

Accuracy of data from various milk networks

In order to combine data from the international, national, and State networks considered in this report, it was first necessary to determine the accuracy with which each laboratory is making its determinations and the agreement of the measurements among the laboratories. The Analytical Quality Control Service of the Office of Radiation Programs conducts periodic studies to assess the accuracy of determinations of radionuclides in milk performed by interested radiochemical laboratories. The generalized procedure for making such a study has been outlined previously (*4*).

The most recent study was conducted during June 1972 with 37 laboratories participating in an experiment on a milk sample containing known concentrations of iodine-131, cesium-137, strontium-89, and strontium-90 (*5*). Of the 18 laboratories producing data for the networks reporting in *Radiation Data and Reports*, 14 participated in the study.

The accuracy results of this study for these 14 laboratories are shown in table 1. The accuracy of the cesium-137 measurements continues to be excellent as in previous experiments. However, both the accuracy and precision need to be improved for iodine-131, strontium-89, and strontium-90 which could probably be accomplished through recalibration.

Development of a common reporting basis

Since the various networks collect and analyze samples differently, a complete understanding of several parameters is useful for interpreting the data. Therefore, the various milk surveillance networks that report regularly were surveyed for information on analytical methods, sampling and analysis frequencies, and estimated analytical errors associated with the data.

In general, radiostrontium is collected by an ion-exchange technique and determined by beta-particle counting in low-background detectors, and the gamma-ray emitters (potassium-40, iodine-131, cesium-137, and barium-140) are determined by gamma-ray spectroscopy of whole milk. Each laboratory has its own modifications and refinements of these basic methodologies.

Many networks collect and analyze samples on a monthly basis. Some collect samples more frequently but composite the several samples for one analysis, while others carry out their analyses more often than once a month. Many networks are analyzing composite samples on a quarterly basis for certain nuclides. The frequency of collection and analysis varies not only among the networks but also at different stations within some of the networks. In addition, the frequency of collection and analysis is a function of current environmental levels. The

Table 1. Distribution of mean results, quality control experiment

Radionuclide and known concentration	Number of laboratories in each category				Experimental 2σ error (pCi/liter)
	Acceptable [a]	Warning level [b]	Unacceptable [c]	Total	
Iodine-131 (96 or 99 pCi/liter)	7 (58%)	1 (8%)	4 (33%)	12	6
Iodine-131 (438 or 484 pCi/liter)	11 (85%)	0	2 (15%)	13	25 or 28
Cesium-137 (53 or 54 pCi/liter)	11 (92%)	0	1 (8%)	12	6
Cesium-137 (295 or 303 pCi/liter)	11 (85%)	2 (15%)	0	13	17
Strontium-89 (29 or 30 pCi/liter)	9 (82%)	0	2 (18%)	11	6
Strontium-89 (197 or 201 pCi/liter)	3 (33%)	1 (11%)	5 (56%)	9	11 or 12
Strontium-90 (32.1 or 32.4 pCi/liter)	4 (33%)	4 (33%)	4 (33%)	12	1.9
Strontium-90 (150.5 or 151.2 pCi/liter)	6 (55%)	0	5 (45%)	11	8.7

[a] Measured concentration equal to or within 2σ of the known concentration.
[b] Measured concentration outside 2σ and equal to or within 3σ of the known concentration.
[c] Measured concentration outside 3σ of the known concentration.

number of samples analyzed at a particular sampling station under current conditions is reflected in the data presentation. Current levels for strontium-90 and cesium-137 are relatively stable over short periods of time, and sampling frequency is not critical. For the short-lived radionuclides, particularly iodine-131, the frequency of analysis is critical and is generally increased at the first measurement or recognition of a new influx of this radionuclide.

The data in table 2 show whether raw or pasteurized milk was collected. An analysis (*6*) of raw and pasteurized milk samples collected during January 1964 to June 1966 indicated that for relatively similar similar milkshed or sampling areas, the differences in concentration of radionuclides in raw and pasteurized milk are not statistically significant (*6*). Particular attention was paid to strontium-90 and cesium-137 in that analysis.

Practical reporting levels were developed by the participating networks, most often based on 2-standard-deviation counting errors or 2-standard-deviation total analytical errors from replicate analyses (*3*). The practical reporting level reflects analytical factors other than statistical radioactivity counting variations and will be used as a practical basis for reporting data.

The following practical reporting levels have been selected for use by all networks whose practical reporting levels were given as equal to or less than the given value.

Radionuclide	Practical reporting level (pCi/liter)
Strontium-89	5
Strontium-90	2
Iodine-131	10
Cesium-137	10
Barium-140	10

Some of the networks gave practical reporting levels greater than those above. In these cases, the larger value is used so that only data considered by the network as meaningful will be presented. The practical reporting levels apply to the handling of individual sample determinations. The treatment of measurements equal to or below these practical reporting levels for calculation purposes, particularly in calculating monthly averages, is discussed in the data presentation.

Analytical error of precision expressed as pCi/liter or percent in a given concentration range has also been reported by the networks (*3*). The precision errors reported for each of the radionuclides fall in the following ranges:

Radionuclide	Analytical errors of precision (2 standard deviations)
Strontium-89	1–5 pCi/liter for levels <50 pCi/liter; 5–10% for levels ≧ 50 pCi/liter;
Strontium-90	1–2 pCi/liter for levels <20 pCi/liter; 4–10% for levels ≧ 20 pCi/liter;
Iodine-131, Cesium-137, Barium-140	4–10 pCi/liter for levels <100 pCi/liter; 4–10% for levels ≧ 100 pCi/liter.

For iodine-131, cesium-137, and barium-140, there is one exception for these precision error ranges: 25 pCi/liter at levels <100 pCi/liter for Colorado. This is reflected in the practical reporting level for the Colorado milk network.

Federal Radiation Council guidance applicable to milk surveillance

In order to place the U.S. data on radioactivity in milk presented in *Radiation Data and Reports* in perspective, a summary of the guidance provided by the Federal Radiation Council for specific environmental conditions was presented in the February 1973 issue of *Radiation Data and Reports.*

Data reporting format

Table 2 presents the integrated results of the international, national, and State networks discussed earlier. Column 1 lists all the stations which are routinely reported in *Radiation Data and Reports.* The relationship between the PMN stations and the State stations is shown in figure 2. The first column in table 2 under each of the reported radionuclides gives the monthly average for the station and the number of samp'es analyzed in that month in parentheses. When an individual sampling result is equal to

Table 2. Concentrations of radionuclides in milk for June 1973 and 12-month period July 1972 through June 1973

Sampling location		Type of sample [1]	Radionuclide concentration (pCi/liter)			
			Strontium-90		Cesium-137	
			Monthly average [1]	12-month average	Monthly average [1]	12-month average
UNITED STATES:						
Ala:	Montgomery [1]	P	NA	5	13	4
Alaska:	Palmer [1]	P	6	4	0	1
Ariz:	Phoenix [1]	P	NA	0	0	0
Ark:	Little Rock [1]	P	15	10	0	2
Calif:	Sacramento [1]	P	NA	1	0	0
	San Francisco [1]	P	NA	0	0	0
	Del Norte	P	15	11	0	7
	Fresno	P	0	1	0	2
	Humboldt	P	3	3	0	2
	Los Angeles	P	0	1	0	2
	Mendocino	P	3	2	0	4
	Sacramento	P	2	2	12	3
	San Diego	P	0	1	0	3
	Santa Clara	P	0	2	0	2
	Shasta	P	2	2	0	4
	Sonoma	P	2	2	0	2
Colo:	Denver [1]	P	3	3	0 (2)	0
	East	R	NA		NA	
	Northeast	R	NA		NA	
	Northwest	R	NA		NA	
	South Central	R	NA		NA	
	Southeast	R	NA		NA	
	Southwest	R	NA		NA	
	West	R	NA		NA	
Conn:	Hartford [1]	P	NA	5	15	5
	Central	P	7	6	3	10
Del:	Wilmington [1]	P	NA	7	14	6
D.C:	Washington [1]	P	NA	5	0	3
Fla:	Tampa [1]	P	3	4	30	31
	Central	R	4	5	29	36
	North	R	6	6	0	13
	Northeast	R	4	5	26	32
	Southeast	R	5	5	32	45
	Tampa Bay area	P	4	5	25	31
	West	R	6	8	0	7
Ga:	Atlanta [1]	P	NS	8	NS	8
Hawaii:	Honolulu [1]	P	0	1	0	0
Idaho:	Idaho Falls [1]	P	5	3	0	0
Ill:	Chicago [1]	P	6	4	0	3
Ind:	Indianapolis [1]	P	NA	4	12	2
	Central	P	7	7	10	7
	Northeast	P	5	5	0	7
	Northwest	P	7	7	0	9
	Southeast	P	7	7	10	6
	Southwest	P	8	7	15	9
Iowa:	Des Moines [1]	P	NA	5	0	0
	Iowa City	P	5	6	0	2
	Des Moines	P	6	5	0 (3)	1
	Le Mars	P	4	4	0	2
	Little Cedar	P	NA	6	0	3
Kans:	Wichita [1]	P	NA	5	0	0
	Coffeyville	P	6	8	0	9
	Dodge City	P	3	4	0	5
	Falls City, Nebr	P	NS	–	NS	–
	Hays	P	5	9	0	6
	Kansas City	P	7	8	0	8
	Topeka	P	8	7	0	5
	Wichita	P	6	8	0	10
Ky:	Louisville [1]	P	NA	6	0	1
La:	New Orleans [1]	P	0	10	0	1
Maine:	Portland [1]	P	NA	5	24	19
Md:	Baltimore [1]	P	NA	6	13	5
Mass:	Boston [1]	P	9	7	14	15
Mich:	Detroit [1]	P	NA	6	0	3
	Grand Rapids [1]	P	NA	7	12	1
	Bay City	P	10	6	0	0
	Charlevoix	P	13	6	2 (5)	4
	Detroit	P	10	4	0	1
	Grand Rapids	P	10	5	0	2
	Lansing	P	11	6	0 (2)	3
	Marquette	P	14 (2)	5	12 (2)	10
	Monroe	P	14	4	0	0
	South Haven	P	18	7	3 (4)	4
Minn:	Minneapolis [1]	P	NA	7	12	8
	Bemidji	P	5	6	0	14
	Duluth	P	20	16	18	21
	Fergus Falls	P	7	7	8	12
	L'ttle Falls	P	15	17	23	33
	Mankato	P	0	4	0	0
	Marshall	P	3	4	0	0

See footnotes at end of table.

Table 2. Concentrations of radionuclides in milk for June 1973 and 12-month period July 1972 through June 1973—continued

Sampling location		Type of sample [4]	Radionuclide concentration (pCi/liter)			
			Strontium-90		Cesium-137	
			Monthly average [4]	12-month average	Monthly average [4]	12-month average
Minn:	Minneapolis	P	11	9	0	12
	Rochester	P	7	7	0	0
Miss:	Jackson [4]	P	NA	8	19	7
Mo:	Kansas City [4]	P	NA	5	0	0
	St. Louis [4]	P	NA	6	0	1
Mont:	Helena [4]	P	NA	4	0	0
Nebr:	Omaha [4]	P	NA	4	0	0
Nev:	Las Vegas [4]	P	NA	1	0	0
N.H:	Manchester [4]	P	NA	6	19	12
N.J:	Trenton [4]	P	NA	6	13	6
N. Mex:	Albuquerque [4]	P	NA	0	0	0
N.Y:	Buffalo [4]	P	4	4	0	3
	New York City [4]	P	NA	8	15	4
	Syracuse [4]	P	NA	6	0	1
	Albany	P	5 (3)	4	0 (3)	0
	Buffalo	P	7	4	10	0
	Massena	P	8	5	23	0
	New York City	P	8	6	0	0
	Syracuse	P	NS	5	NS	0
N.C:	Charlotte [4]	P	NA	7	11	6
N. Dak:	Minot [4]	P	NA	8	0	1
Ohio:	Cincinnati [4]	P	NA	5	0	2
	Cleveland [4]	P	NA	6	13	3
Okla:	Oklahoma City [4]	P	NA	4	0	0
Oreg:	Portland [4]	P	6	4	0	2
	Baker	P	NA		NA	
	Coos Bay	P	NA		NA	
	Eugene	P	NA		NA	
	Medford	P	NA		NA	
	Portland composite	P	NA		NA	
	Portland local	P	NA		NA	
	Redmond	P	NA		NA	
	Tillamook	P	NA		NA	
Pa:	Philadelphia [4]	P	NA	6	11	2
	Pittsburgh [4]	P	NA	8	14	6
	Dauphin	P	3	5	0	2
	Erie	P	5	7	0	3
	Philadelphia	P	3	4	0	3
	Pittsburgh	P	7	6	0	4
R.I:	Providence [4]	P	NA	5	0	8
S.C:	Charleston [4]	P	5	7	17	8
	Chapin	R	NS	8	NS	11
	Clemson	R	8	7	12	5
	Columbia	R	8	7	9	10
	Fairfield	R	NS	7	NS	13
	Hartsville–02	R	NS	6	NS	15
	Hartsville–03	R	NS	18	NS	18
	Lee County	R	NS	8	NS	18
	Oconee County	R	NS	8	NS	7
	Pickens	R	NS	7	NS	4
	Williston	R	7	7	14	15
	Winnsboro	R	NS	8	NS	24
S. Dak:	Rapid City [4]	P	NA	5	0	0
Tenn:	Chattanooga [4]	P	NA	8	12	6
	Memphis [4]	P	NA	6	12	2
	Chattanooga	P	NA	8	16	7
	Clinton	R	NA	7	0 (2)	7
	Fayetteville	R	NA	8	0 (2)	5
	Kingston	R	NA	7	0 (2)	1
	Knoxville	R	NA	6	0 (2)	3
	Lawrenceburg	R	NS	6	NS	8
	Nashville	R	NS	7	NS	2
	Pulaski	R	NA	6	0 (2)	3
	Sequoyah	R	NS	7	NS	6
Tex:	Austin [4]	P	NA	2	0	0
	Dallas [4]	P	NA	5	0	0
	Amarillo	R	NA		NA	
	Corpus Christi	R	NA		NA	
	El Paso	R	NA		NA	
	Fort Worth	R	NA		NA	
	Harlingen	R	NA		NA	
	Houston	R	NA		NA	
	Lubbock	R	NA		NA	
	Midland	R	NA		NA	
	San Antonio	R	NA		NA	
	Texarkana	R	NA		NA	
	Uvalde	R	NA		NA	
	Wichita Falls	P	NA		NA	
Utah:	Salt Lake City [4]	P	3	3	0	2
Vt:	Burlington [4]	P	NA	5	13	8
Va:	Norfolk [4]	P	NA	6	11	3
Wash:	Seattle [4]	P	NA	4	0	1
	Spokane	P	NA	4	0	1

See footnotes at end of table.

Table 2. Concentrations of radionuclides in milk for June 1973 and 12-month period July 1972 through June 1973—continued

Sampling location	Type of sample [a]	Radionuclide concentration (pCi/liter)			
		Strontium-90		Cesium-137	
		Monthly average [b]	12-month average	Monthly average [b]	12-month average
Wash: Benton County	R	NS	1	NS	0
Franklin County	R	0	1	0	0
Longview	R	5	3	13	3
Sandpoint, Idaho	R	6	6	0	3
Skagit County	R	5	6	0	3
W. Va: Charleston [c]	P	NA	7	17	5
Wisc: Milwaukee [c]	P	NA	5	0	2
Wyo: Laramie [c]	P	NA	2	0	0
CANADA:					
Alberta: Calgary	P	5	5	9	10
Edmonton	P	5	6	11	15
British Columbia: Vancouver	P	8	7	16	15
Manitoba: Winnipeg	P	4	5	13	12
New Brunswick: Moncton	P	8	7	12	9
Newfoundland: St. John's	P	11	16	17	21
Nova Scotia: Halifax	P	6	7	9	12
Ontario: Ottawa	P	5	6	5	7
Sault Ste. Marie	P	10	10	16	18
Thunder Bay	P	8	9	NS	18
Toronto	P	4	3	5	7
Windsor	P	2	3	3	7
Quebec: Montreal	P	5	5	7	8
Quebec	P	8	8	NS	8
Saskatchewan: Regina	P	5	5	5	9
Saskatoon	P	5	6	7	9
CENTRAL AND SOUTH AMERICA:					
Canal Zone: Cristobal [c]	P	NA	1	0	12
Chile: Santiago	P	0	1	0	1
Colombia: Bogota	P	0	0	0	0
Ecuador: Guayaquil	P	0	0	0	0
Jamaica: Montego Bay	P	NS	2	NS	39
Puerto Rico: San Juan [c]	P	NA	1	11	2
Venzuela: Caracas	P	3	1	0	2
PMN network average [e]		5	5	6	4

[a] P, pasteurized milk.
R, raw milk.

[b] When an individual sampling result was equal to or less than the practical reporting level, a value of "0" was used for averaging. Monthly averages less than the practical reporting level reflect the fact that some but not all of the individual samples making up the average contained levels greater than the practical reporting level. When more than one analysis was made in a month period, the number of samples in the monthly average is given in parentheses.

[c] Pasteurized Milk Network station. All other sampling locations are part of the State or National network.

[d] The practical reporting level for this network differs from the general ones given in the text. Sampling results for these networks were equal to or less than the following practical reporting levels:
Cesium-137: Colorado—25 pCi/liter; Oregon—15 pCi/liter.

[e] This entry gives the average radionuclide concentrations for the Pasteurized Milk Network stations denoted by footnote [c].

NA, no analysis.
NS, no sample collected.

or below the practical reporting level for the radionuclide, a value of zero is used for averaging. Monthly averages are calculated using the above convention. Averages which are equal to or less than the practical reporting levels reflect the presence of radioactivity in some of the individual samples greater than the practical reporting level.

The second column under each of the radionuclides reported gives the 12-month average

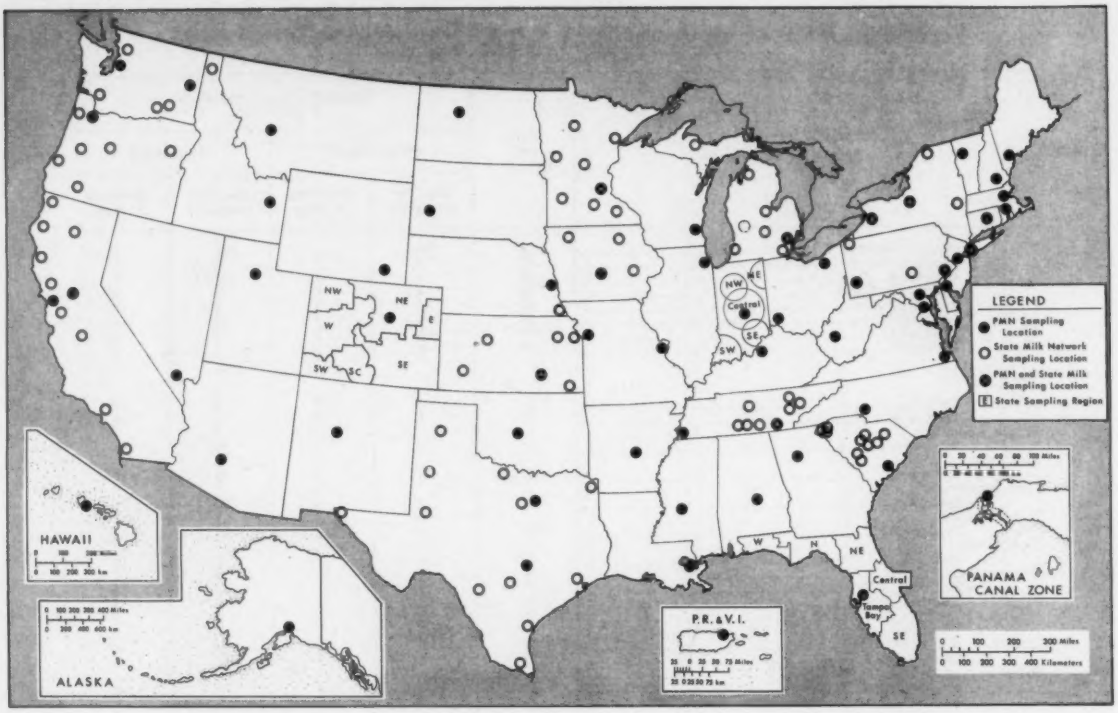

Figure 2. State and PMN sampling stations in the United States

for the station as calculated from the preceding 12 monthly averages, giving each monthly average equal weight. Since the daily intake of radioactivity by exposed population groups, averaged over a year, constitutes an appropriate criterion for the case where the FRC radiation protection guides apply, the 12-month average serves as a basis for comparison.

Discussion of current data

In table 2, surveillance results are given for strontium-90 and cesium-137 for June 1973 and the 12-month period, July 1972 to June 1973. Except where noted, the monthly average represents a single sample for the sampling station. Strontium-89, iodine-131, and barium-140 data have been omitted from table 2 since levels at all of the stations for June 1973 were below the respective practical reporting levels.

Strontium-90 monthly averages ranged from 0 to 20 pCi/liter in the United States for June 1973 and the highest 12-month average was 18 pCi/liter (Hartsville-03, S.C.) representing 9.0 percent of the Federal Radiation Council radiation protection guide. Cesium-137 monthly averages ranged from 0 to 82 pCi/liter in the United States for June 1973, and the highest 12-month average was 45 pCi/liter (Southeast Florida) representing 1.3 percent of the value derived from the recommendations given in the Federal Radiation Council report.

Acknowledgement

Appreciation is expressed to the personnel of the following agencies who provide data from their milk surveillance networks:

Environmental Control Component
Radiologic Health Section
California Department of Health

Radiation Protection Division
Canadian Department of National Health and Welfare

Radiological Health Section
Division of Occupational and Radiological Health
Colorado Department of Health

Laboratory Division
Connecticut Department of Health

Radiological and Occupational Health Section
Department of Health and Rehabilitative Services
State of Florida

Bureau of Environmental Sanitation
Division of Sanitary Engineering
Indiana State Board of Health

Division of Radiological Health
Environmental Engineering Services
Iowa State Department of Health

Radiation Control Section
Environmental Health Division
Kansas State Department of Health

Radiological Health Services
Division of Occupational Health
Michigan Department of Health

Radiation Control Section
Division of Environmental Health
State of Minnesota Department of Health

Bureau of Radiological Pollution Control
New York State Department of Environmental Conservation

Environmental Radiation Surveillance Program
Division of Sanitation and Engineering
Oregon State Board of Health

Radiological Health Section
Bureau of Environmental Health
Pennsylvania Department of Public Health

Division of Radiological Health
South Carolina State Board of Health

Radiological Health Services
Division of Preventable Diseases
Tennessee Department of Public Health

Division of Occupational Health
Environmental Health Services
Texas State Department of Health

Radiation Control Section
Division of Health
Washington Department of Social and Health Services

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(*2*) U.S. ATOMIC ENERGY COMMISSION, DIVISION OF ISOTOPES DEVELOPMENT. Chart of the Nuclides, Tenth Edition revised to December 1968. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

(*3*) NATIONAL CENTER FOR RADIOLOGICAL HEALTH. Section I. Milk Surveillance. Radiol Health Data Rep 9:730–746 (December 1968).

(*4*) ROSENSTEIN, M. and A. S. GOLDIN. Statistical technics for quality control of environmental radioassay. Health Lab Sci 2:93 (April 1965).

(*5*) BARATTA, E. J. and F. E. KNOWLES, JR. Interlaboratory study of iodine-131, cesium-137, strontium-89, and strontium-90 measurements in milk, June 1972, Technical experiment 72 MKAQ-1. Analytical Quality Control Service, Office of Radiation Programs, EPA, Washington, D.C. 20460 (December 1972).

(*6*) ROBINSON, P. B. A comparison of results between the Public Health Service Raw Milk and Pasteurized Milk Networks for January 1964 through June 1966. Radiol Health Data Rep 9:475–488 (September 1968).

Milk Surveillance Network, April-May 1973

National Environmental Research Center—
Las Vegas, Environmental Protection Agency

The Milk Surveillance Network,[1] operated by the National Environmental Research Center—Las Vegas (NERC-LV) consists of 24 routine and two alternate sampling locations (figure 1) situated in the offsite area surrounding the Nevada Test Site (NTS). This routine network is operated in support of the nuclear testing conducted by the U.S. Atomic Energy Commission (AEC) at the Nevada Test Site.

In the event of a release of radioactivity from the NTS, special sampling within the affected

[1] This network is operated under a Memorandum of Understanding (No. AT(26-1)-539) with the Nevada Operations Office, U.S. AEC, Las Vegas, Nev.

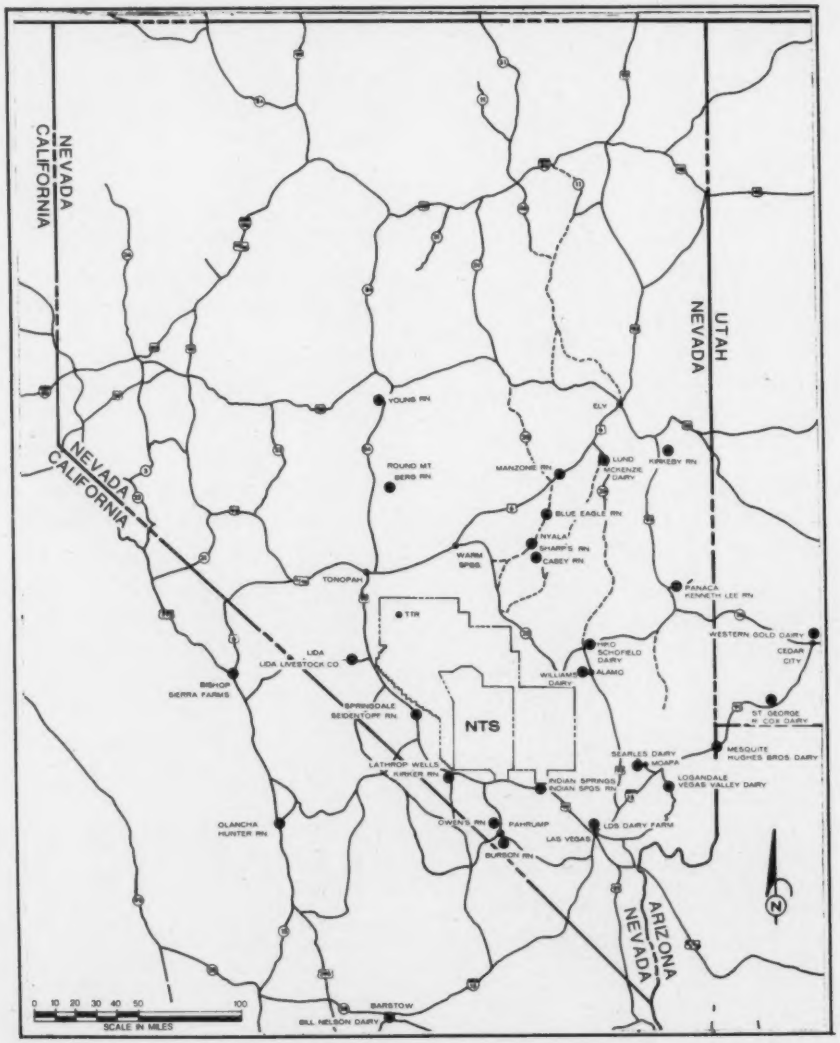

Figure 1. NERC-LV Milk Surveillance Network

area is conducted to determine radionuclide concentrations. Additional milk sampling networks are operated in support of AEC operations in areas other than the NTS when requested. A complete description of sampling and analytical procedures was included with the milk results reported in the July 1973 issue of *Radiation Data and Reports.*

Results

The analytical results of all milk samples collected in April and May 1973 by NERC-LV surveillance programs are listed in tables 1 and 2. With the exception of cesium-137 at levels near the minimum detectable activity (MDA) of 10 pCi/liter, no gamma-emitting fission products were identified by gamma spectrometry in any of the samples collected during April and

Table 1. Milk surveillance results, April 1973

Location	Date collected (1973)	Sample type [a]	Radionuclide concentrations [b] (pCi/liter)			
			Cesium-137	Strontium-89	Strontium-90	Tritium
California:						
Bishop:						
Sierra Farms	4/11	11	<10	<2.0	<1.2	NA
Hinkley:						
Bill Nelson Dairy	4/9	12	<10	<2.0	<1.0	NA
Olancha:						
Hunter Ranch	4/10	13	<10	<2.0	<1.0	NA
Nevada:						
Alamo:						
Williams Dairy	4/10	12	<10	<2.0	<1.2	NA
Austin:						
Young's Ranch	4/9	13	<10	<2.0	2.3±1.3	630±250
Currant:						
Blue Eagle Ranch	4/16	13	10	<3.0	2.4±1.6	NA
Manzonie Ranch	4/17	13	<10	<3.0	2.1±1.7	NA
Hiko:						
Schofield Dairy	4/10	12	<10	<2.0	<1.1	<250
Indian Springs:						
Indian Springs Ranch	NS					
Las Vegas:						
LDS Dairy Farms	4/13	12	<10	<1.0	<.9	<250
Lathrop Wells:						
Kirker Ranch	4/11	13	<10	<2.0	<1.2	NA
Lida:						
Lida Livestock Company	4/9	13	<10	<2.0	<1.0	NA
Logandale:						
Vegas Valley Dairy	4/9	12	<10	<2.0	<1.1	NA
Lund:						
McKenzie Dairy	4/16	12	<10	<3.0	1.7±1.6	<240
Mesquite:						
Hughes Bros. Dairy	4/10	12	13	<2.0	1.9±1.2	<250
Moapa:						
Searles Diary	4/10	12	<10	<2.0	2.0±1.4	NA
Nyala:						
Sharp's Ranch	4/11	13	<100	<2.0	<1.0	<250
Pahrump:						
Owens Ranch	4/11	13	<10	<1.0	<.9	NA
Panaca:						
Kenneth Lee Ranch	NS					
Round Mountain:						
Berg Ranch	4/9	13	<10	<3.0	3.8±1.8	NA
Shoshone:						
Kirkeby Ranch	4/15	13	<10	<2.0	<1.3	NA
Springdale:						
Seidentopf Ranch	4/10	13	<10	<2.0	<1.1	NA
Utah:						
Cedar City:						
Western Gold Dairy	4/10	12	<10	<2.0	1.7±1.2	NA
St. George:						
R. Cox Dairy	4/11	12	<10	<2.0	<1.1	NA

[a] 11—Pasteurized milk.
12—Raw milk from Grade A producer(s).
13—Raw milk from family cow(s).
[b] Two-sigma counting error provided when available.
[c] Small sample size increased MDA.
NA, no analysis.
NS, no sample.

May. Levels of tritium near the MDA for this radionuclide (200 pCi/liter) were also measured by liquid scintillation counting technique. The highest concentration of tritium during April was 630 ± 260 pCi/liter while all concentrations during May were <240 pCi/liter.

Table 2. Milk surveillance results, May 1973

Location	Date collected (1973)	Sample type [a]	Radionuclide concentrations [b] (pCi/liter)			
			Cesium-137	Strontium-89	Strontium-90	Tritium
California:						
Bishop:						
Sierra Farms	5/1	11	<10	NA	NA	NA
Hinkley:						
Bill Nelson Dairy	5/1	12	<10	NA	NA	NA
Olancha:						
Hunter Ranch	5/3	13	<10	NA	NA	NA
Nevada:						
Alamo:						
Williams Dairy	5/1	12	<10	NA	NA	NA
Austin:						
Young's Ranch	NS					
Currant:						
Blue Eagle Ranch	5/7	13	[c] <100	NA	NA	NA
Manzonie Ranch	5/8	13	<10	NA	NA	NA
Hiko:						
Schofield Dairy	5/1	12	<10	NA	NA	<240
Indian Springs:						
Indian Springs Ranch	NS					
Las Vegas:						
LDS Dairy Farms	5/3	12	<10	NA	NA	<230
Lathrop Wells:						
Kirker Ranch	5/9	13	<10	NA	NA	NA
Lida:						
Lida Livestock Company	5/1	13	<10	NA	NA	NA
Logandale:						
Vegas Valley Dairy	5/1	12	<10	NA	NA	NA
Lund:						
McKenzie Dairy	5/8	12	<10	NA	NA	<230
Mesquite:						
Hughes Bros. Dairy	5/1	12	<10	NA	NA	<230
Moapa:						
Searles Dairy:	5/1	12	12	NA	NA	NA
Nyala:						
Sharp's Ranch	5/2	13	[c] <100	NA	NA	<240
Pahrump:						
Owens Ranch	5/8	13	<10	NA	NA	NA
Panaca:						
Owens Ranch	NS					
Round Mountain:						
Berg Ranch	5/1	13	<10	NA	NA	NA
Shoshone:						
Kirkeby Ranch	5/9	13	<10	NA	NA	NA
Springdale:						
Seidentopf Ranch	5/9	13	<10	NA	NA	NA
Utah:						
Cedar City:						
Western Gold Dairy	5/1	12	<10	NA	NA	NA
St. George:						
R. Cox Dairy	5/2	12	<10	NA	NA	NA

[a] 11—Pasteurized milk.
12—Raw milk from Grade A producer(s).
13—Raw milk from family cow(s).
[b] Two-sigma counting error provided when available.
[c] Small sample size increased minimum detectable activity.
NA, no analysis.
NS, no sample.

Food and Diet Surveillance

Efforts are being made by various Federal and State agencies to estimate the dietary intake of selected radionuclides on a continuing basis. These estimates, along with the guidance developed by the Federal Radiation Council, provide a basis for evaluating the significance of radioactivity in foods and diet.

Networks presently in operation and reported routinely include those listed below. These networks provide data useful for developing estimates of nationwide dietary intake of radionuclides. Programs reported in *Radiation Data and Reports* are as follows:

Program	Period reported	Issue
California Diet Study	January–June 1971	December 1972
Carbon-14 in Total Diet and Milk	July–December 1971	May 1972
Institutional Diet	October–December 1972 and 1972 Annual Summary	September 1973
Radiostrontium in Milk	1971	November 1972
Strontium-90 in Tri-City Diets	1971	December 1972

SECTION II. WATER

The Environmental Protection Agency and other Federal, State, and local agencies operate extensive water quality sampling and analysis programs for surface, ground, and treated water. Most of these programs include determinations of gross beta and gross alpha radioactivity and specific radionuclides.

Although the determination of the total radionuclide intake from all sources is of primary importance, a measure of the public health importance of radioactivity levels in water can be obtained by comparison of the observed values with the Public Health Service Drinking Water Standards (*1*). These standards, based on consideration of Federal Radiation Council (FRC) recommendations (*2–4*) set the limits for approval of a drinking water supply containing radium-226 and strontium-90 at 3 pCi/liter and 10 pCi/liter, respectively. Higher concentrations may be acceptable if the total intake of radioactivity from all sources remains within the guides recommended by FRC for control action. In the known absence[1] of strontium-90 and alpha-particle emitters, the limit is 1,000 pCi/liter gross beta radioactivity, except when additional analysis indicates that concentrations of radionuclides are not likely to cause exposures greater than the limits indicated by the Radiation Protection Guides. Surveillance data from a number of Federal and State programs are published periodically to show current and long-range trends. Water sampling activities reported in *Radiation Data and Reports* are listed below.

[1] Absence is taken to mean a negligibly small fraction of the specific limits of 3 pCi/liter and 10 pCi/liter for unidentified alpha-particle emitters and strontium-90, respectively.

Water sampling program	Period reported	Issue
California	1970	June 1972
Colorado River Basin	1968	March 1972
Community Water Supply Study	1968	September 1972
Florida	1969	January 1972
Interstate Carrier Drinking Water	1971	May 1972
Kansas	1971	February 1973
Michigan	January–June 1970	November 1971
Minnesota	July 1970–June 1971	November 1972
New York	July–December 1971	August 1973
North Carolina	1968–1970	September 1972
Radiostrontium in Tap Water, *HASL*	July–December 1971	November 1972
Tritium Surveillance	January–March 1973	July 1973
Washington	July 1970–June 1971	August 1973
Water Surveillance Programs, *NERC-LV*	March 1973	September 1973

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(*2*) FEDERAL RADIATION COUNCIL. Radiation Protection Guidance for Federal Agencies, Memorandum for the President, September 1961. Reprint from the Federal Register of September 26, 1961.

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Tritium Surveillance System, April-June 1973

Office of Radiation Programs
Environmental Protection Agency

The Tritium Surveillance System is an expansion of previous tritium surveillance activities initiated by the Public Health Service and transferred in 1970 to the Office of Radiation Programs, Environmental Protection Agency (EPA). The principal effort in the past related to tritium releases was the Tritium in Surface Water Network. This network was established in 1964 to measure and monitor tritium concentrations in major river systems in the United States and to provide surveillance at surface water stations downstream from selected nuclear facilities. The network consisted of selected stations from the existing water pollution surveillance sampling stations. The final data from this network for January–June 1970, have been published previously (*1*).

Another sampling program of the Public Health Service was a tritium in precipitation program. This project was established in 1967 at selected Radiation Alert Network (RAN) stations covering the United States, including Alaska and Hawaii. The RAN is now operated by the Office of Air Programs of the EPA. The data from this project for July–December 1969 have been published previously (*2*). Due to the increased interest in tritium releases from nuclear facilities and the potential long-term accumulation in the environment, a national system was established to incorporate these projects or networks into one overall system.

Present network

The Tritium Surveillance System consists of 68 quarterly drinking water samples at the RAN stations, precipitation samples collected daily and analyzed monthly from 8 of the RAN stations (figure 1), and quarterly samples at

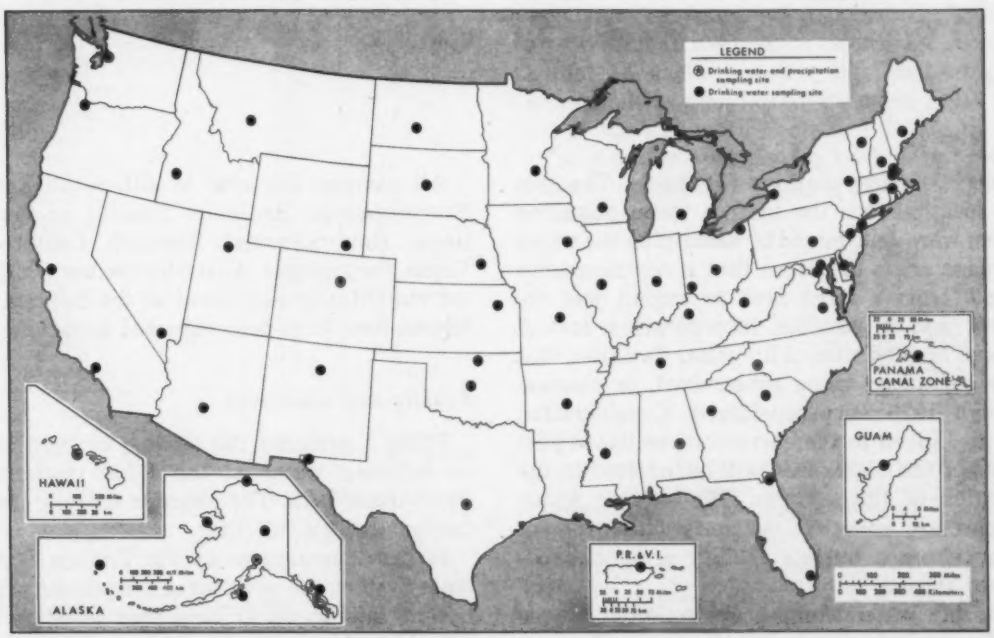

Figure 1. Drinking water and precipitation sampling locations for tritium surveillance system

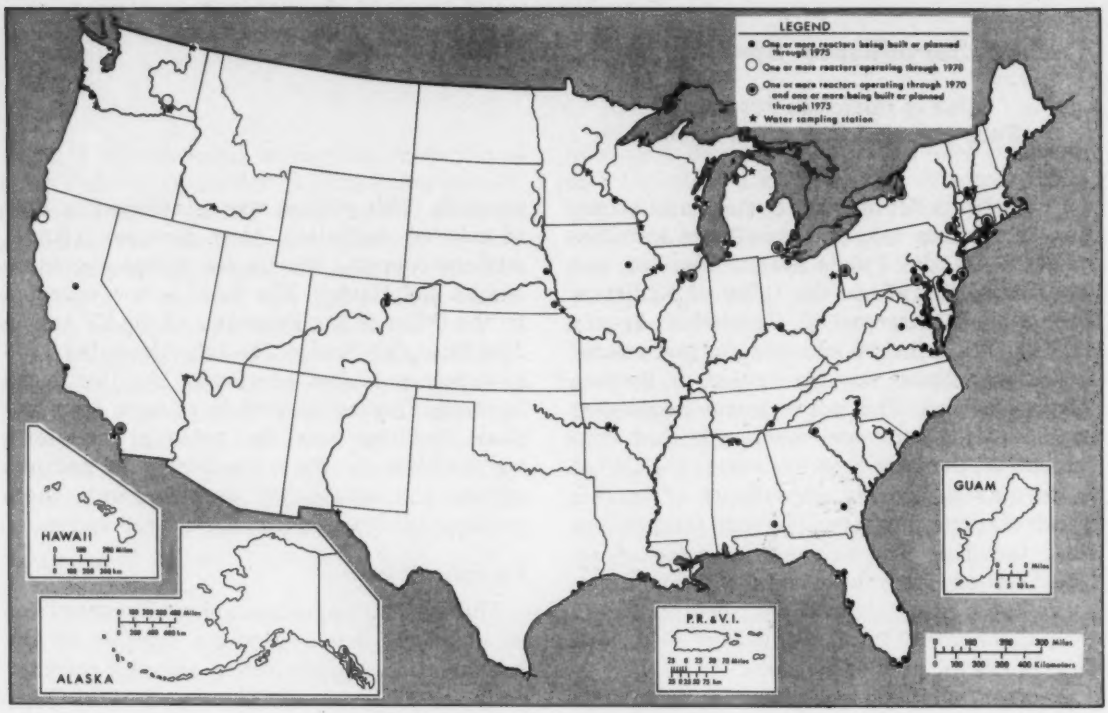

Figure 2. Surface water sampling locations for tritium surveillance system

39 surface water stations (figure 2). The specific locations for the surface water sampling system were determined by examining the water drainage areas to assure that a representative sample from a large area or region was obtained, and if possible, incorporating several nuclear facility sites. All nuclear facilities that were operating, being constructed, or planned through 1975 were considered. Consideration was also given to the current surveillance programs of the States that will be involved in the collection of the samples. The surface water samples are collected quarterly either downstream from a nuclear facility or at a background station.

The tap water samples are collected by the RAN operators on a quarterly basis. The precipitation samples are also collected by the RAN operators on a daily basis.

All samples are sent to either the Eastern Environmental Radiation Facility or the National Environmental Research Center—Las Vegas, for analysis. Analytical values which are not statistically significant at the 2-sigma confidence level have been reported as zero.

Results and discussion

Table 1 presents the tritium concentrations in drinking water at the RAN stations for April–June 1973. The average tritium concentration was 0.2 nCi/liter.

In previous articles on the Tritium Surveillance System, the reported dose equivalents from tritium in body water have been based on a relationship derived by Moghissi and Porter (*3*). Their relationship assumed a quality factor of 1.7 for tritium beta rays based on a 1966 ICRP

Table 1. Tritium concentration in tap-water (RAN stations), April-June 1973

Location		Date collected (1973)	Tritium concentration[a] (nCi/liter ±2σ)[b]
Ala:	Montgomery	4/2	0.0
Alaska:	Anchorage	4/2	.5±0.3
	Attu Island	4/2	0 ± .3
	Fairbanks	4/7	.5± .3
	Juneau	4/5	0 ± .3
	Nome	4/16	.5± .3
	Point Barrow	4/2	.4± .3
Ariz:	Phoenix	4/23	.3
Ark:	Little Rock	4/2	0 ± .3
Calif:	Berkeley	4/4	0 ± .3
	Los Angeles	4/2	0 ± .3
C.Z:	Ancon	4/16	0
Colo:	Denver	4/16	.8± .3
Conn:	Hartford	4/4	0
Del:	Dover	4/6	0
D.C:	Washington	4/2	.2
Fla:	Jacksonville	4/2	0
	Miami	4/2	0
Ga:	Atlanta	4/11	.2
Guam:	Agana	4/2	0 ± .3
Hawaii:	Honolulu	4/5	0 ± .3
Idaho:	Boise	4/3	0 ± .3
Ill:	Springfield	4/3	.3
Ind:	Indianapolis	4/3	.2
Iowa:	Iowa City	4/2	0 ± .3
Kans:	Topeka	4/10	0 ± .3
Ky:	Frankfort	4/5	0
La:	New Orleans	4/10	.3± .3
Maine:	Augusta	4/3	0
Md:	Baltimore	4/2	.2
Mass:	Lawrence	4/2	0
	Winchester	4/3	.2
Mich:	Lansing	4/3	0
Minn:	Minneapolis	4/9	.3
Miss:	Jackson	4/2	0
Mo:	Jefferson City	4/3	0 ± .3
Mont:	Helena	4/2	0 ± .3
Nebr:	Lincoln	4/2	0 ± .3
Nev:	Las Vegas	4/3	.6± .3
N.H:	Concord	4/2	.3
N.J:	Trenton	4/3	0
N. Mex:	Sante Fe	4/3	0 ± .3
N.Y:	Albany	4/4	0
	Buffalo	4/3	.3
	New York City	4/6	0
N.C:	Gastonia	4/2	.2
N. Dak:	Bismarck	5/1	1.0± .3
Ohio:	Cincinnati	4/6	.4
	Columbus	4/3	0
	Painesville	4/2	.4
Okla:	Oklahoma City	4/11	0
Oreg:	Portland	4/2	0 ± .3
Pa:	Harrisburg	4/12	0
P.R:	San Juan	4/3	0
R.I:	Providence	4/6	0
S.C:	Columbia	4/2	.2
S. Dak:	Pierre	4/2	.5± .3
Tenn:	Nashville	4/2	0
Tex:	Austin	4/5	0 ± .3
	El Paso	4/3	0 ± .3
Utah:	Salt Lake City	4/2	0 ± .3
Vt:	Barre	4/2	.2
Va:	Richmond	4/5	.2
Wash:	Seattle	4/11	0
	Spokane	4/2	0 ± .3
W. Va:	Charleston	4/2	.2
Wisc:	Madison	4/6	.2
Wyo:	Cheyenne	4/3	.9± .3
Average			0.2

[a] The minimum detection limit for all samples was 0.20 nCi/liter. All values equal to or less than 0.20 nCi/liter before rounding have been reported as zero.

[b] The 2σ error for all samples is 0.2 nCi/liter unless otherwise noted.

recommendation (*4*). Recently, the NCRP has recommended a quality factor of 1 for tritium beta rays (*5*) and this recommendation has been adopted for this and subsequent reports. Following the notation adopted by the ICRU (*6*), substitution of a quality factor of 1 in Moghissi and Porter calculations yields:

$$\dot{H}\ (\text{mrem/year}) = 0.1C\ (\text{nCi/liter})$$

Where $\dot{H}$ is the dose equivalent rate and C represents the tritium concentration in body water.

Assuming that the concentration of tritium in all water taken into the body is equal to that found in the drinking water and also that the specific activity of tritium in the body is essentially the same as that in the drinking water, then the radiation dose may be estimated.

The highest individual concentration of tritium observed in the drinking water was 1.0 nCi/liter during the second quarter. This corresponds to a dose of 0.1 mrem/a, or less than 0.06 percent of the Federal Radiation Council's Radiation Protection Guide (170 mrem/a) for an average dose to a suitable sample of the exposed population.

The tritium concentrations for the surface water samples are given in table 2. The highest tritium concentration was 2.8 nCi/liter for the second quarter. Assuming that the specific activity of tritium in the body is essentially the same as that in surface water, this concentration corresponds to a dose of 0.3 mrem/a, or 0.2 percent of the Radiation Protection Guide.

The monthly analyses for tritium in precipitation samples at the 8 RAN stations are shown in table 3.

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(*2*) BUREAU OF RADIOLOGICAL HEALTH. Tritium in precipitation (RAN), July–December 1969. Radiol Health Data Rep 11:354–355 (July 1970).

(*3*) MOGHISSI, A. A. and C. R. PORTER. Tritium in surface waters in the United States, 1966. Radiol Health Data Rep 9:337–339 (July 1968).

Table 2. Tritium concentration in surface water, April–June 1973

Location		Water source	Facility	Collection date (1973)	Concentration [a] (nCi/liter ± 2σ)[b]
Ala:	Decatur	Tennessee River	Browns Ferry	4/3	0.3
Ark:	Morrilton	Arkansas River	Arkansas Nuclear	4/2	0 ±0.3
Calif:	Eureka	Humboldt Bay	Humboldt Bay	4/7	0 ± .3
	San Onofre	Pacific Ocean	San Onofre	4/10	0
Colo:	Greely	South Platte River	Fort St. Vrain	4/16	.7± .3
Conn:	East Haddam	Connecticut River	Connecticut Yankee & Vermont Yankee	4/24	1.9
	Waterford	Long Island Sound	Millstone	4/25	0
Fla:	Crystal River	Gulf of Mexico	Crystal River	4/17	0
	Homestead	Biscayne Bay	Turkey Point	4/12	0
Idaho:	Buhl	Snake River	National Reactor Testing Station	4/2	0 ± .3
Ill:	Moline	Mississippi River	Quad-Cities	4/30	.2
	Morris	Illinois River	Dresden and Argonne	4/6	.2
La:	New Orleans	Mississippi River	(Several)	4/2	0 ± .3
Md:	Conowingo	Susquehanna River	Peach Bottom and Three Mile Island	4/11	0
	Lusby	Chesapeake Bay	Calvert Cliffs	4/3	0
Mass:	Rowe	Deerfield River	Yankee	4/4	.5
Mich:	Charlevoix	Lake Michigan	Big Rock Point	4/5	.2
	Monroe	Lake Erie	Enrico Fermi	4/12	.3
	South Haven	Lake Michigan	Palisades	4/10	0
Minn:	Monticello	Mississippi River	Monticello	4/9	.4
Nebr:	Rulo	Missouri River	Fort Calhoun and Cooper	4/4	0 ± .3
Nev:	Boulder City	Colorado River	Background	4/3	.9± .3
N.J:	Bayside	Delaware River	Salem	4/27	.2
N.Y:	Ossining	Hudson River	Indian Point	4/4	.3
	Oswego	Lake Ontario	Nine Mile Point and R. E. Ginna	4/10	.4
	Poughkeepsie	Hudson River	Background	4/4	.2
N.C:	Charlotte	Catawba River	Wm. B. McGuire	4/5	0
Oreg:	Westport	Columbia River	Trojan and Hanford	NS	
S.C:	Allendale	Savannah River	Savannah River Plant and Oconee	[c]3/22	2.8
	Hartsville	Lake Robinson	H. B. Robinson	3/16	1.6
Tenn:	Kingston	Clinch River	Oak Ridge	4/10	2.3
Tex:	El Paso	Rio Grande	Los Alamos	4/2	0 ± .3
Vt:	Vernon	Connecticut River	Vermont Yankee	4/3	.2
Va:	Newport News	James River	Surry	[c]3/29	0
Wash:	Northport	Columbia River	Background	4/9	.4± .3
	Richland	Columbia River	Hanford	4/4	.5± .3
W. Va:	Wheeling	Ohio River	Shippingport	4/4	.2
Wisc:	Two Creeks	Lake Michigan	Point Beach and Kewaunee	4/16	0
	Victory	Mississippi River	LaCrosse and Prairie Island	4/12	.2
Average					0.4

[a] The minimum detection limit for all samples was 0.20 nCi/liter. All values equal to or less than 0.20 nCi/liter before rounding have been reported as zero.
[b] The 2σ error for all samples is 0.2 nCi/liter unless otherwise noted.
[c] Sample collected early.
NS, no sample.

Table 3. Tritium concentration in precipitation from RAN stations, April–June 1973

Location		Tritium concentration [a] (nCi/liter ± 2σ)		
		April	May	June
Ala:	Montgomery	0.0	0.0	0.0
Alaska:	Anchorage	[b].2	[b].2	[b].2
Colo:	Denver	.6	.6	0
Hawaii:	Honolulu	0	0	0
La:	New Orleans	0	0	0
N.C:	Gastonia	.9	.3	.7
Tex:	Austin	0	.2	0
Wash:	Seattle	.2	.2	0

[a] The minimum detection limit for these samples was 0.20 nCi/liter. All values equal to or less than 0.20 nCi/liter before rounding have been reported as zero. The 2σ error for all samples is 0.2 nCi/liter unless otherwise noted.
[b] Composite sample for March–June 1973.

(4) INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Recommendations of the International Commission on Radiological Protection (Adopted September 17, 1965), ICRP Publication 9 (1969).

(5) NATIONAL COUNCIL ON RADIATION PROTECTION AND MEASUREMENTS. Basic Radiation Protection Criteria, NCRP Report No. 39, National Council on Radiation Protection and Measurements, Washington, D.C. 20008 (January 15, 1971).

(6) INTERNATIONAL COMMISSION ON RADIATION UNITS AND MEASUREMENTS, Radiation Quantities and Units, ICRU Report No. 19, Washington, D.C. 20014 (July 1972).

Other coverage in *Radiation Data and Reports:*

Period	Issue
April–June 1972	January 1973
July–September 1972	February 1973
October–December 1972	May 1973
January–March 1973	July 1973

Water Surveillance Programs, April-May 1973

National Environmental Research Center—
Las Vegas, Environmental Protection Agency

The Water Surveillance Network,[1] operated by the National Environmental Research Center—Las Vegas (NERC-LV), consists of 61 sampling locations (figures 1 and 2) in the offsite area surrounding the Nevada Test Site (NTS). This routine network is operated in support of the nuclear testing programs conducted by the U.S. Atomic Energy Commission (AEC) at the Nevada Test Site.

In the event of a release from the NTS, special sampling within the affected area is conducted to determine radionuclide concentrations. Additional water sampling networks are

[1] This network is operated under a Memorandum of Understanding (No. AT-(26-1)-539) with the Nevada Operations Office, U.S. AEC, Las Vegas, Nev.

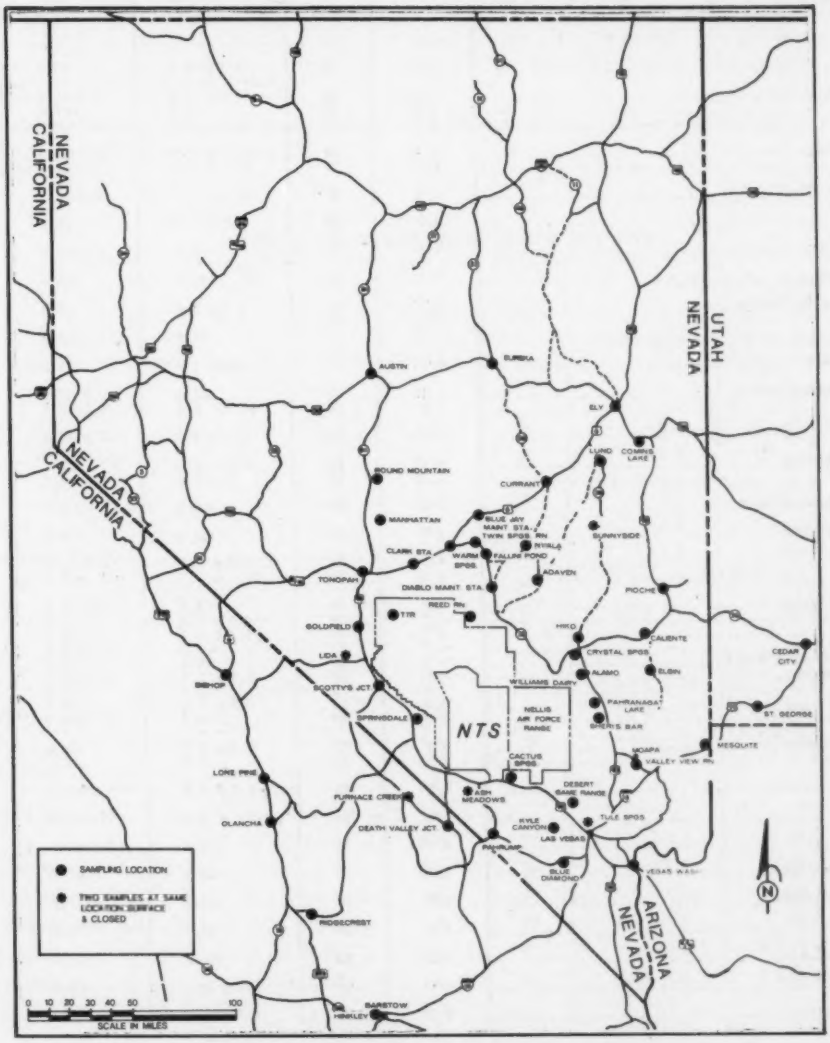

Figure 1. NERC-LV Water Surveillance Network

Table 1. Water surveillance results, April 1973

Location	Date collected (1973)	Sample type [a]	Radioactivity concentrations [b] (pCi/liter)		
			Gross alpha	Gross beta	Tritium
California:					
Bishop:					
Fish and Game Office	4/11	23	<1.6	<3.0	NA
Death Valley Junction:					
Lila's Cafe	4/12	23	<5.2	<3.2	<250
Furnace Creek:					
Pond	4/12	21	<3.8	5.8±3.3	NA
Visitor Center	4/12	27	<3.3	<3.1	NA
Hinkley:					
Bill Nelson Dairy	4/9	23	5.9± 5.0	<3.1	NA
Lone Pine:					
Forest Service Ranger Station	4/10	23	<1.8	<3.0	NA
Olancha:					
Haiwee Reservoir	4/10	21	7.1± 4.0	<3.0	NA
Ridgecrest:					
City Hall	4/10	23	<3.0	<3.1	NA
Nevada:					
Adaven:					
Canfield Ranch	4/3	22	5.4± 3.6	<3.5	NA
Alamo:					
Pahranagat Lake	4/10	21	8.0± 5.6	6.5±3.1	NA
Sheri's Bar	4/10	23	<2.4	<3.4	NA
Williams Dairy	4/10	23	7.8± 4.8	9.5±3.9	NA
Ash Meadows:					
Ash Meadows Lodge	4/10	23	12 ± 7.8	12 ±3.8	<250
Pond	4/10	21	18 ± 9.6	17 ±4.2	NA
Austin:					
Nevada National Bank	4/9	27	24 ± 6.5	6.3±3.3	NA
Blue Diamond:					
Post Office	4/9	23	4.2± 3.9	<3.3	<250
Blue Jay Highway:					
Maintenance Station	4/10	23	<2.4	2.8±2.8	NA
Cactus Springs:					
Mobil Service Station	4/11	27	<2.4	<3.0	<250
Caliente:					
Agricultural Extension Station	4/12	23	4.5± 3.9	<2.8	NA
Clark Station:					
Five Mile Ranch	4/10	27	<1.9	4.2±2.9	NA
Currant:					
Currant Ranch Cafe	4/17	27	4.2± 3.6	<3.5	NA
Diablo:					
Highway Maintenance Station	4/11	23	<3.1	2.9±2.8	NA
Reed Ranch	4/9	21	15 ± 6.3	6.7±3.3	NA
Elgin:					
Water tower	4/12	23	5.6± 4.0	9.3±3.9	NA
Ely:					
Chevron Service Station	4/18	24	3.2± 2.6	<3.4	NA
Comins Lake	4/16	21	<2.3	6.8±3.6	NA
Eureka:					
Highway Maintenance Station	4/2	24	<2.8	<3.5	NA
Goldfield:					
Chevron Service Station	4/9	23	<3.1	<2.8	NA
Hiko:					
Crystal Springs	4/10	27	6.2± 4.2	3.6±2.8	NA
Schofield Dairy	4/10	23	21 ± 7.7	30 ±4.9	NA
Las Vegas:					
Craig Ranch Golf Course	4/9	23	<2.6	4.2±3.3	<250
Desert Game Range	4/9	23	4.3± 3.2	<3.3	<250
Lab II, NERC	4/9	24	5.4± 5.1	7.3±3.6	870±260
Lake Mead Vegas Wash	4/9	21	<4.0	6.3±3.6	750±270
Las Vegas Water District Well 28	4/9	23	<2.5	<3.3	<250
Municipal Golf Course	4/9	23	3.5± 3.0	3.4±3.3	<250
Tule Springs	4/9	23	<2.6	<3.3	<250
Tule Springs Pond	4/9	21	5.3± 3.4	<3.3	NA
Vegas Estates	4/9	23	<3.4	13 ±4.0	<260
Lida:					
Lida Livestock Company	4/9	27	2.9± 2.7	<3.4	NA
Pond at storage tank	4/9	21	<3.1	<2.8	NA
Lund:					
Gardner Grocery	4/17	23	3.0± 2.6	<3.4	NA
Manhattan:					
Country store	4/10	23	12 ± 6.2	<2.8	NA
Mesquite:					
Hughes Bros. Dairy	4/10	23	<3.6	3.1±2.9	NA
Moapa:					
Pedersen Valley View Ranch	4/10	27	<3.0	<3.0	NA
Mt. Charleston:					
Kyle Canyon Fire Station	4/9	27	<2.3	<3.3	<250
Nyala:					
Sharp's Ranch	4/11	23	<2.5	<2.8	NA
Pahrump:					
Texaco Service Station	4/11	23	<2.9	<3.0	NA
Ploche:					
County courthouse	4/11	24	2.3± 2.1	<3.4	NA
Round Mountain:					
Mobil Service Station	4/10	27	2.0± 1.8	<3.4	NA

See footnotes at end of table.

Table 1. Water surveillance results, April 1973—continued

Location	Date collected (1973)	Sample type [a]	Radioactivity concentrations [b] (pCi/liter)		
			Gross alpha	Gross beta	Tritium
Scotty's Junction:					
Chevron Service Station	4/9	23	<5.0	3.5±2.9	340±240
Springdale:					
Pond	4/10	21	<4.4	6.3±3.4	NA
Sunnyside:					
Adam McGill Reservoir	4/17	21	8.5± 4.4	<3.4	NA
Wildlife Management Headquarters	4/17	27	<2.1	<3.4	NA
Tonopah:					
Jerry's Chevron Station	4/12	23	4.0± 2.9	4.5±3.5	NA
Tonopah Test Range CP-1	4/11	23	3.2± 3.0	6.9±3.7	NA
Warm Springs:					
Fallini's Pond	4/11	21	25 ±13	46 ±6.1	NA
Service Station and Cafe	4/10	27	35 ±12	28 ±4.5	NA
Twin Springs Ranch	4/11	23	<4.2	3.1±2.8	NA
Utah:					
Cedar City:					
M. D. Baldwin residence	4/11	24	<3.6	<3.1	NA
St. George:					
R. Cox Dairy	4/11	24	5.9± 3.1	<3.0	NA

[a] 21—Pond, lake, reservoir, stock tank, stock pond.
22—Stream, river, creek.
23—Well.
24—Multiple supply—mixed (A water sample consisting of mixed or multiple sources of water, such as well and spring.)
27—Spring.
[b] Two-sigma counting error provided when available.
NA, no analysis.

Table 2. Water surveillance results, May 1973

Location	Date collected (1973)	Sample type [a]	Radioactivity concentrations [b] (pCi/liter)		
			Gross alpha	Gross beta	Tritium
California:					
Bishop:					
Fish and Game Office	5/2	23	<0.7	<3.3	NA
Death Valley Junction:					
Lila's Cafe	5/3	23	<3.3	3.7±3.9	390±240
Furnace Creek:					
Pond	5/3	21	4.1± 3.9	11 ±3.9	NA
Visitor Center	5/3	27	<2.6	7.9±3.7	NA
Hinkley:					
Bill Nelson Dairy	5/1	23	4.3± 3.7	6.8±3.6	NA
Lone Pine:					
Forest Service Ranger Station	5/3	23	<1.4	<3.3	NA
Olancha:					
Haiwee Reservoir	5/2	21	3.9± 4.1	6.1±3.5	NA
Ridgecrest:					
City Hall	5/1	23	3.9± 3.4	<3.4	NA
Nevada:					
Adaven:					
Canfield Ranch	5/1	22	2.4± 2.3	<3.5	NA
Alamo:					
Pahranagat Lake	5/1	21	6.6± 4.6	11 ±4.1	NA
Sheri's Bar	5/1	23	5.2± 4.1	4.0±3.7	NA
Williams Dairy	5/1	23	4.9± 4.2	6.5±3.8	NA
Ash Meadows:					
Ash Meadows Lodge	NS				
Pond	NS				
Austin:					
Nevada National Bank	NS				
Blue Diamond:					
Post Office	5/1	23	<2.8	<3.5	<240
Blue Jay Highway:					
Maintenance Station	5/2	23	<2.6	<3.5	NA
Cactus Springs:					
Mobil Service Station	5/7	27	<1.3	<3.3	<240
Caliente:					
Agricultural Extension Station	5/2	23	5.4± 3.5	<3.6	NA
Clark Station:					
Five Mile Ranch	5/2	27	<2.4	5.8±3.6	NA
Currant:					
Currant Ranch Cafe	5/3	27	7.9± 4.5	5.6±3.5	NA

See footnotes at end of table.

Table 2. Water surveillance results, May 1973—continued

Location	Date collected (1973)	Sample type [a]	Radioactivity concentrations [b] (pCi/liter)		
			Gross alpha	Gross beta	Tritium
Diablo:					
Highway Maintenance Station	5/2	23	<2.6	7.8±3.8	NA
Reed Ranch	5/1	21	9.2± 5.0	14 ±4.1	NA
Elgin:					
Water tower	5/2	23	3.7± 3.2	<3.6	NA
Ely:					
Chevron Service Station	5/7	24	2.9± 2.3	3.4±3.3	NA
Comins Lake	5/7	21	8.5± 4.7	23 ±4.5	NA
Eureka:					
Highway Maintenance Station	5/1	24	2.9± 2.8	<3.5	NA
Goldfield:					
Chevron Service Station	5/1	23	<2.9	<3.6	NA
Hiko:					
Crystal Springs	5/1	27	5.5± 3.6	<3.6	NA
Schofield Dairy	5/1	23	24 ± 3.3	23 ±4.9	NA
Las Vegas:					
Craig Ranch Golf Course	5/1	23	3.5± 2.7	<3.5	<240
Desert Game Range	5/1	23	3.2± 2.5	<3.5	<240
Lab II, NERC	5/1	24	5.8± 4.6	6.0±3.8	800±250
Lake Mead Vegas Wash	5/1	21	4.9± 4.2	6.3±3.8	1000±250
Las Vegas Water District Well 28	5/22	23	<1.6	<3.3	<250
Municipal Golf Course	5/1	23	3.6± 2.6	<3.5	<240
Tule Springs	5/1	23	4.3± 2.8	<3.5	<240
Tule Springs Pond	5/1	21	3.1± 2.4	<3.5	NA
Vegas Estates	5/1	23	<3.5	6.4±3.8	<240
Lida:					
Lida Livestock Company	5/1	27	<2.6	<3.4	NA
Pond at storage tank	5/1	21	<1.6	<3.4	NA
Lund:					
Gardner Grocery	5/8	23	<2.2	<3.3	NA
Manhattan:					
Country store	5/1	23	15 ± 6.5	<3.7	NA
Mesquite:					
Hughes Bros. Dairy	5/1	23	3.8± 3.6	<3.6	NA
Moapa:					
Pedersen Valley View Ranch	5/1	27	4.1± 3.9	3.3±3.9	NA
Mt. Charleston:					
Kyle Canyon Fire Station	5/1	27	<2.2	<3.5	350±240
Nyala:					
Sharp's Ranch	5/2	23	<1.7	<3.5	NA
Pahrump:					
Texaco Service Station	5/7	23	2.5± 2.3	<3.3	NA
Ploche:					
County courthouse	5/2	24	<2.5	<3.6	NA
Round Mountain:					
Mobil Service Station	5/1	27	<1.7	<3.3	NA
Scotty's Junction:					
Chevron Service Station	5/1	23	5.4± 4.6	6.9±3.9	280±240
Springdale:					
Pond	5/9	21	4.0± 3.7	7.7±3.7	NA
Sunnyside:					
Adam McGill Reservoir	5/8	21	7.5± 4.0	7.2±3.6	NA
Wildlife Management Headquarters	5/8	27	2.7± 2.3	<3.3	NA
Tonopah:					
Jerry's Chevron Station	5/1	23	<1.9	<3.6	NA
Tonopah Test Range CP-1	5/2	23	<2.6	<3.6	NA
Warm Springs:					
Fallini's Pond	5/2	21	25 ±11	52 ±6.4	NA
Service Station and Cafe	5/1	27	15 ± 7.5	27 ±5.0	NA
Twin Springs Ranch	5/1	23	4.6± 3.6	9.6±3.9	NA
Utah:					
Cedar City:					
M. D. Baldwin residence	5/2	24	<1.4	<3.5	NA
St. George:					
R. Cox Dairy	5/2	24	5.7± 2.7	<3.5	NA

[a] 21—Pond, lake, reservoir, stock tank, stock pond.
22—Stream, river, creek.
23—Well.
24—Multiple supply—mixed (A water sample consisting of mixed or multiple sources of water, such as well and spring.)
27—Spring.

[b] Two-sigma counting error provided when available.
NA, no analysis.
NS, no sample.

operated in support of AEC operations in areas other than the NTS when requested. A complete description of sampling and routine analytical procedures was included with the water results reported in the July 1973 issue of *Radiation Data and Reports.*

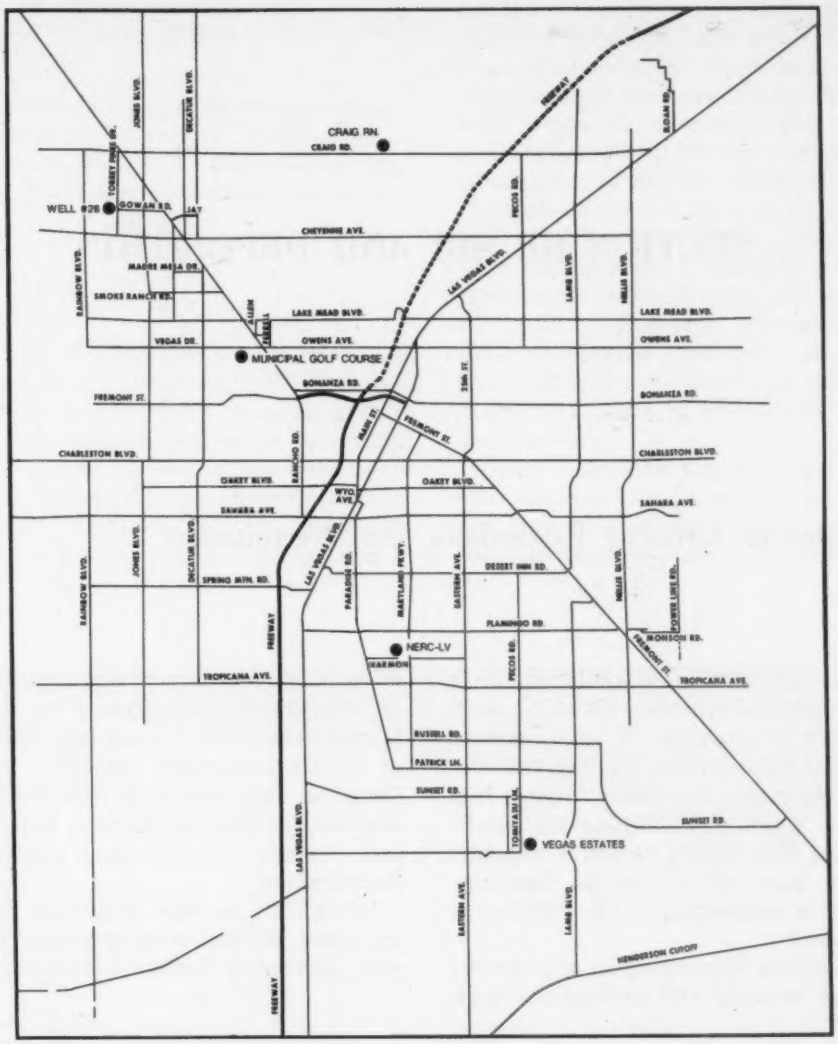

Figure 2. NERC-LV Water Surveillance Network, Las Vegas Valley

Results

The routine analytical results of all water samples collected in April and May 1973 by the NERC-LV water surveillance network are listed in tables 1 and 2. No gamma-emitting fission products were identified by gamma spectrometry in any of the April and May samples. The analytical results for calendar year 1973 samples selected for special analyses will be reported at a later date.

SECTION III. AIR AND DEPOSITION

Radioactivity in Airborne Particulates and Precipitation

Continuous surveillance of radioactivity in air and precipitation provides one of the earliest indications of changes in environmental fission product radioactivity. To date, this surveillance has been confined chiefly to gross beta radioanalysis. Although such data are insufficient to assess total human radiation exposure from fallout, they can be used to determine when to modify monitoring in other phases of the environment.

Surveillance data from a number of programs are published monthly and summarized periodically to show current and long-range trends of atmospheric radioactivity in the Western Hemisphere. These include data from activities of the Environmental Protection Agency, the Canadian Department of National Health and Welfare, the Mexican National Institute of Nuclear Energy, and the Pan American Health Organization.

In addition to those programs presented in this issue, the following programs were previously covered in *Radiation Data and Reports.*

Network	Period	Issue
Plutonium in airborne particulates	October–December 1972	June 1973
Surface air sampling program, 80th Meridian Network, *HASL*	January–December 1971	September 1973
Fallout in the United States and other areas	1971	August 1973

1. Radiation Alert Network June 1973

Quality Assurance and Environmental Monitoring Laboratory, National Environmental Research Center—Research Triangle Park, Environmental Protection Agency

Surveillance of atmospheric radioactivity in the United States is conducted by the Radiation Alert Network (RAN) which regularly gathers samples at 68 locations distributed throughout the country (figure 1). Most of the stations are operated by State health department personnel.

The station operators perform "field estimates" on the airborne particulate samples at 5 hours after collection, when most of the radon daughter products have decayed, and at 29 hours after collection, when most of the thoron daughter products have decayed. They also perform field estimates on dried precipitation samples and report all results to appropriate Environmental Protection Agency officials by mail or telephone depending on levels found. A compilation of the daily field estimates is available upon request from the Quality Assurance and Environmental Monitoring Laboratory, NERC-RTP, EPA, Research Triangle Park, N.C. 27711. A detailed description of the sampling and analytical procedures was presented in the March 1968 issue of *Radiological Health Data and Reports.*

Table 1 presents the monthly average gross beta radioactivity in surface air particulates and deposition by precipitation, as measured by the field estimate technique, during June 1973.

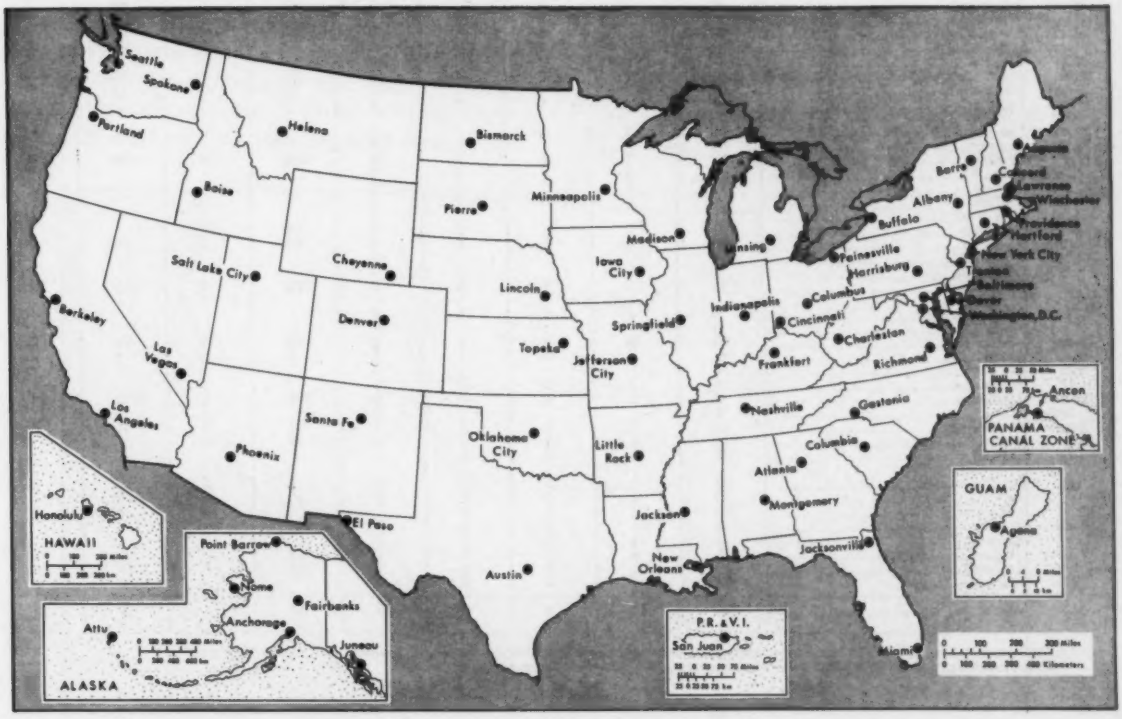

Figure 1. Radiation Alert Network sampling stations

Table 1. Gross beta radioactivity in surface air and precipitation, June 1973

Station location		Number of samples	Gross beta radioactivity (5-hour field estimate) (pCi/m³)			Number of samples	Total depth (mm)	Precipitation		
								Field estimation of deposition		
			Maximum	Minimum	Average [a]			Number of samples	Depth (mm)	Total deposition (nCi/m²)
Ala:	Montgomery	15	2	0	1	4	82	4	82	12
Alaska:	Anchorage	1	0	0	0	0				
	Attu Island	29	1	0	0	0				
	Fairbanks	0				0				
	Juneau	0				0				
	Nome	0				0				
	Point Barrow	0				0				
Ariz:	Phoenix	21	7	0	3	0				
Ark:	Little Rock	0				0				
Calif:	Berkeley	21	0	0	0	0				
	Los Angeles	19	2	0	1	0				
C.Z:	Ancon	14	0	0	0	0				
Colo:	Denver	20	5	1	2	1	2	[b]		
Conn:	Hartford	21	1	0	0	8	106	8	106	0
Del:	Dover	20	1	0	0	0				
D.C:	Washington	0				0				
Fla:	Jacksonville	18	0	0	0	9	144	9	144	13
	Miami	1	0	0	0	0				
Ga:	Atlanta	0				0				
Guam:	Agana	0				0				
Hawaii:	Honolulu	20	1	0	0	2	7	[b]		
Idaho:	Boise	15	1	0	1	1	10	1	10	0
Ill:	Springfield	5	2	0	1	0				
Ind:	Indianapolis	20	3	0	1	0				
Iowa:	Iowa City	21	4	0	1	6	95	6	95	0
Kans:	Topeka	20	4	0	2	4	65	4	65	0
Ky:	Frankfort	18	2	0	1	0				
La:	New Orleans	20	2	0	0	10	144	[b]		
Maine:	Augusta	21	1	0	0	10	124	10	124	0
Md:	Baltimore	21	1	0	0	5	38	5	38	0
Mass:	Lawrence	21	2	0	0	7	69	7	69	0
	Winchester	20	1	0	0	9	260	9	260	0
Mich:	Lansing	21	1	0	0	9	83	9	83	8
Minn:	Minneapolis	14	2	0	1	3	54	3	54	15
Miss:	Jackson	0				0				
Mo:	Jefferson City	21	2	0	1	8	96	8	96	0
Mont:	Helena	18	2	0	1	2	11	2	11	0
Nebr:	Lincoln	20	13	1	3	1	3	1	3	1
Nev:	Las Vegas	20	2	0	1	0				
N.H:	Concord	0				0				
N.J:	Trenton	21	1	0	0	10	126	10	126	3
N. Mex:	Santa Fe	2	2	0	1	0				
N.Y:	Albany	11	1	0	0	0				
	Buffalo	20	1	0	0	0				
	New York City	0				0				
N.C:	Gastonia	21	7	1	2	3	47	[b]		
N. Dak:	Bismarck	20	4	0	2	4	33	4	33	0
Ohio:	Cincinnati	0				0				
	Columbus	0			0	0				
	Painesville	21	1	0	0	8	123	8	123	31
Okla:	Oklahoma City	9	2	0	1	0				
	Ponca City	0				0				
Oreg:	Portland	20	0	0	0	6	57	6	57	2
Pa:	Harrisburg	16	2	0	1	1	1	1	1	0
P.R:	San Juan	0				0				
R.I:	Providence	19	1	0	0	0				
S.C:	Columbia	9	3	0	0	6	221	6	221	0
S. Dak:	Pierre	0				0				
Tenn:	Nashville	18	1	0	1	5	71	5	71	5
Tex:	Austin	19	3	1	1	5	89	[b]		
	El Paso	20	4	1	1	0				
Utah:	Salt Lake City	28	2	0	1	2	5	2	5	1
Vt:	Barre	15	2	0	1	8	123	8	123	7
Va:	Richmond	18	2	0	0	1	17	1	17	1
Wash:	Seattle	9	0	0	0	5	118	[b]		
	Spokane	11	1	0	0	0				
W. Va:	Charleston	19	3	0	1	6	89	5	49	3
Wisc:	Madison	19	2	0	1	8	38	8	38	1
Wyo:	Cheyenne	14	6	0	2	0				
Network summary		915	13	0	1	177	94	6	78	4

[a] The monthly average is calculated by weighting the field estimates of individual air samples with length of sampling period.
[b] This station is part of the tritium surveillance system. No gross beta measurements are done.

2. Air Surveillance Network June 1973

National Environmental Research Center—Las Vegas,[1] Environmental Protection Agency

The Air Surveillance Network[2] (ASN), operated by the National Environmental Research Center—Las Vegas (NERC-LV), consists of 49 active and 73 standby sampling stations located in 21 western States (figures 2 and 3). The network is operated in support of nuclear testing sponsored by the Atomic Energy Commission (AEC) at the Nevada Test Site (NTS), and at any other designated testing sites.

The stations are operated by State health department personnel and by private individuals on a contract basis. All active stations are operated continuously with filters being exchanged over periods generally ranging from 24 to 72 hours. The standby stations were activated on June 29 to monitor radioactive fallout from a nuclear detonation conducted by the People's Republic of China on June 26, 1973. However, many of the State and federal agencies at which standby sampling stations are located were closed over the weekend of June 30–July 1 resulting in only one or two samples being collected at 46 locations in June. All samples are mailed to the NERC-LV unless special retrieval is arranged at selected locations in response to known releases of radioactivity from the NTS. A complete description of sampling and analytical procedures was presented in the February 1972 issue of *Radiation Data and Reports.*

Results

Table 2 presents the average gross beta concentrations in air for each of the network stations. The minimum reporting concentration for gross beta is 0.1 pCi/m³. For reporting purposes, concentrations less than 1.0 pCi/m³ are reported to one significant figure, and those equal to or greater than 1.0 pCi/m³ are reported to two significant figures. For averaging purposes, individual concentration values less than the minimum detectable concentration (MDC) (0.06 pCi/m³ for a 350 m³ sample) are set equal to the minimum detectable concentration. Reporting and roundoff conventions are indicated as follows:

[1] Formerly the Western Environmental Research Laboratory.

[2] The ASN is operated under a Memorandum of Understanding (No. AT-(26-1)-539) with the Nevada Operations Office, U.S. Atomic Energy Commission.

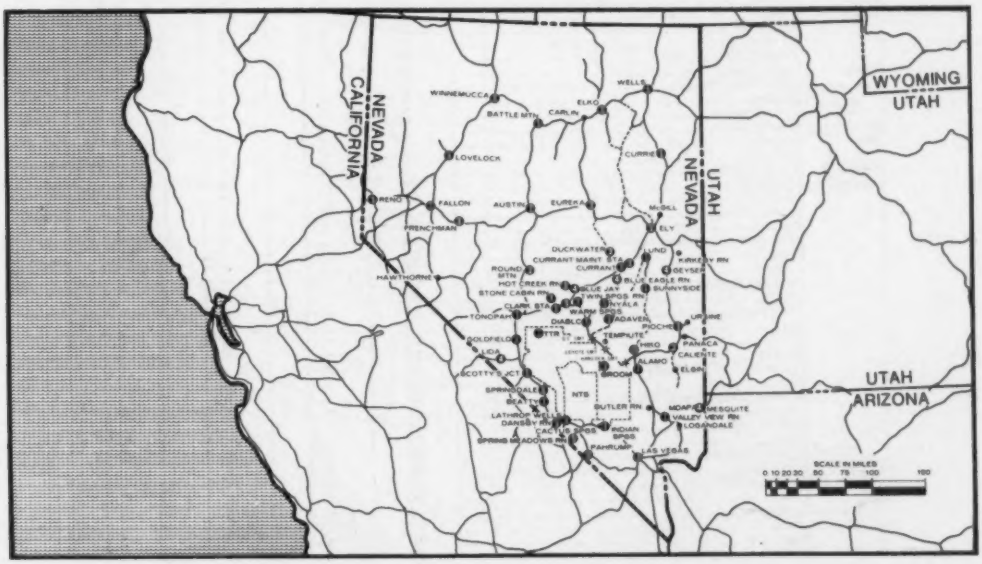

Figure 2. NERC-LV Air Surveillance Network stations in Nevada

Concentration (pCi/m³)	Reported value of concentration above MDC (pCi/m³)	Reported value of concentration concentration below MDC (pCi/m³)
<0.05	<0.1	<0.1
≧ .05 <0.15	.1	< .1
≧ .15	As calculated and rounded	< calculated MDC

As shown in table 2, the highest gross beta concentration within the network was 0.2 pCi/m³ at Diablo, Nev. No radionuclides were identified by gamma spectrometry on any filters or charcoal cartridges during June.

Complete copies of this summary and listings of the daily gross beta and gamma spectrometry results are distributed to EPA regional offices and appropriate State agencies. Additional copies of the daily results may be obtained from the NERC-LV upon written request.

Table 2. Summary of gross beta radioactivity concentrations in air, June 1973

Location		Number of samples	Concentration (pCi/m³)		
			Maximum	Minimum	Average *
Ariz:	Kingman	30	<0.1	<0.1	<0.1
	Phoenix	2	<.1	<.1	<.1
	Seligman	28	.1	<.1	.1
	Winslow	2	<.1	<.1	<.1
Ark:	Little Rock	1	<.1	<.1	<.1
Calif:	Baker	23	.1	<.1	.1
	Barstow	30	<.1	<.1	<.1
	Bishop	30	<.1	<.1	<.1
	Death Valley Junction	29	<.2	<.1	<.1
	Furnace Creek	27	<.1	<.1	<.1
	Lone Pine	27	<.1	<.1	<.1
	Needles	27	.1	<.1	.1
	Ridgecrest	30	.1	<.1	.1
	Shoshone	30	<.1	<.1	<.1
Colo:	Denver	1	<.1	<.1	<.1
Idaho:	Boise	2	<.1	<.1	<.1
	Idaho Falls	2	<.1	<.1	<.1
	Preston	1	<.1	<.1	<.1
	Twin Falls	2	<.1	<.1	<.1
Iowa:	Iowa City	2	<.1	<.1	<.1
La:	Lake Charles	2	<.1	<.1	<.1
	Monroe	2	<.1	<.1	<.1
	New Orleans	2	<.1	<.1	<.1
Minn:	Minneapolis	1	<.1	<.1	<.1
Mo:	Clayton	1	<.1	<.1	<.1
	Joplin	2	<.1	<.1	<.1
Nebr:	North Platte	2	<.1	<.1	<.1
Nev:	Alamo	29	<.1	<.1	<.1
	Austin	18	.1	<.1	.1
	Battle Mountain	2	<.1	<.1	<.1
	Beatty	29	<.1	<.1	<.1
	Blue Eagle Ranch (Currant)	29	.1	<.1	.1
	Blue Jay	30	<.1	<.1	<.1
	Caliente	29	<.1	<.1	<.1
	Currant Ranch	29	<.2	<.1	<.1
	Diablo	30	.2	<.1	.1
	Duckwater	27	<.1	<.1	<.1
	Elko	2	<.1	<.1	<.1
	Ely	28	<.1	<.1	<.1
	Eureka	29	<.1	<.1	<.1
	Fallini's Twin Springs Ranch	30	<.1	<.1	<.1
	Fallon	2	<.1	<.1	<.1
	Geyser Maintenance Station	29	<.1	<.1	<.1
	Goldfield	30	<.2	<.1	<.1
	Groom Lake	18	.1	<.1	.1
	Hiko	30	<.1	<.1	<.1
	Indian Springs	30	<.1	<.1	<.1
	Las Vegas	21	.1	<.1	.1
	Lathrop Wells	28	<.1	<.1	<.1
	Lida	24	<.1	<.1	<.1
	Lovelock	1	<.1	<.1	<.1
	Lund	30	<.1	<.1	<.1
	Mesquite	30	<.1	<.1	<.1
	Nyala	30	<.1	<.1	<.1

See footnote at end of table.

Table 2. Summary of gross beta radioactivity concentrations in air, June 1973—continued

Location		Number of samples	Concentration (pCi/m³)		
			Maximum	Minimum	Average *
	Pahrump	27	<.2	<.1	<.1
	Pioche	27	<.1	<.1	<.1
	Reno	2	<.2	<.1	<.1
	Round Mountain	30	<.1	<.1	<.1
	Scotty's Junction	27	.1	<.1	.1
	Stone Cabin Ranch	30	<.1	<.1	<.1
	Sunnyside	30	<.1	<.1	<.1
	Tonopah	26	<.1	<.1	<.1
	Tonopah Test Range	29	.1	<.1	.1
	Warm Springs	28	<.1	<.1	<.1
	Warm Springs Ranch	30	<.1	<.1	<.1
	Wells	2	<.1	<.1	<.1
	Winnemucca	2	<.1	<.1	<.1
N. Mex:	Albuquerque	1	<.1	<.1	<.1
	Carlsbad	1	<.1	<.1	<.1
Okla:	Muskogee	2	<.1	<.1	<.1
Oreg:	Burns	2	<.1	<.1	<.1
	Medford	10	<.1	<.1	<.1
S. Dak:	Aberdeen	1	<.1	<.1	<.1
	Rapid City	1	<.1	<.1	<.1
Tex:	Abilene	2	<.1	<.1	<.1
	Amarillo	2	<.1	<.1	<.1
	Fort Worth	2	<.1	<.1	<.1
Utah:	Cedar City	26	<.1	<.1	<.1
	Delta	30	<.2	<.1	<.1
	Dugway	2	<.1	<.1	<.1
	Enterprise	2	<.1	<.1	<.1
	Garrison	29	.1	<.1	.1
	Logan	2	<.1	<.1	<.1
	Milford	30	<.1	<.1	<.1
	Monticello	2	<.1	<.1	<.1
	Parowan	2	<.1	<.1	<.1
Utah:	Provo	2	<.1	<.1	<.1
	Roosevelt	1	<.1	<.1	<.1
	Salt Lake City	2	<.1	<.1	<.1
	St. George	29	<.1	<.1	<.1
	Wendover	2	<.1	<.1	<.1
Wash:	Seattle	2	<.1	<.1	<.1
	Spokane	1	<.1	<.1	<.1
Wyo:	Rock Springs	3	<.1	<.1	<.1
	Worland	2	<.1	<.1	<.1

* Individual values less than the minimum detectable concentration (MDC) are set equal to the MDC for averaging. A monthly average less than the minimum reportable value of 0.1 pCi/m³ is reported as <0.1.

Figure 3. NERC-LV Air Surveillance Network outside Nevada

3. Canadian Air and Precipitation Monitoring Program[a] June 1973

Radiation Protection Division
Department of National Health and Welfare

The Radiation Protection Division of the Canadian Department of National Health and Welfare monitors surface air and precipitation in connection with its Radioactive Fallout Study Program. Twenty-four collection stations are located at airports (figure 4), where the sampling equipment is operated by personnel from the Meteorological Services Branch of the Department of Transport. Detailed discussions of the sampling procedures, methods of analysis, and interpretation of results of the radioactive fallout program are contained in reports of the Department of National Health and Welfare (*1–5*).

A summary of the sampling procedures and methods of analysis was presented in the May 1969 issue of *Radiological Health Data and Reports.*

[a] Prepared from information and data obtained from the Canadian Department of National Health and Welfare, Ottawa, Canada.

Surface air and precipitation data for June 1973 are presented in table 3.

Table 3. Canadian gross beta radioactivity in surface air and precipitation, June 1973

Station	Number of samples	Air surveillance gross beta radioactivity (pCi/m³)			Precipitation measurements	
		Maximum	Minimum	Average	Average concentration (pCi/liter)	Total deposition (nCi/m²)
Calgary	5	0.02	<0.01	0.02	3	0.2
Coral Harbour	5	.02	<.01	.01	8	.2
Edmonton	5	.02	.01	.01	1	.1
Ft. Churchill	4	.01	<.01	<.01	42	.4
Fredericton	6	.02	<.01	.01	5	.4
Goose Bay	6	<.01	<.01	<.01	.2	.2
Halifax	4	.01	.01	.01	5	.6
Inuvik	6	.01	<.01	.01	18	.7
Montreal	5	.02	<.01	.01	5	.4
Moosonee	4	.01	<.01	.01	17	.8
Ottawa	5	.02	<.01	.01	7	.8
Quebec	6	.01	<.01	.01	6	.7
Regina	5	.02	.01	.01	12	.9
Resolute	5	.01	<.01	.01	23	.1
St. John's, Nfld.	1	<.01	<.01	<.01	12	1.8
Saskatoon	6	.01	.01	.01	8	.9
Sault Ste. Marie	5	.02	<.01	.01	25	1.6
Thunder Bay	6	.02	<.01	.01	8	.7
Toronto	4	.02	.01	.02	8	.5
Vancouver	5	.01	<.01	.01	9	.5
Whitehorse	4	.01	<.01	.01	13	.2
Windsor	6	.02	.01	.01	3	.6
Winnipeg	5	.02	.01	.02	9	.9
Yellowknife	4	.01	<.01	<.01	30	.4
Network summary	115	0.02	<0.01	0.01	12	0.6

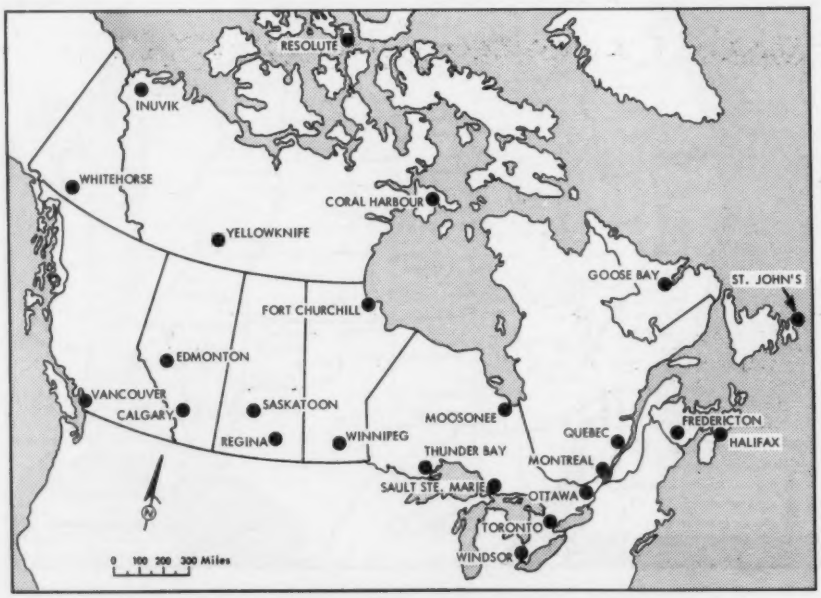

Figure 4. Canadian air and precipitation sampling stations

4. Pan American Air Sampling Program June 1973

Pan American Health Organization and U.S. Environmental Protection Agency

Gross beta radioactivity in air is monitored by countries in the Americas under the auspices of the collaborative program developed by the Pan American Health Organization (PAHO) and the Environmental Protection Agency (EPA) to assist PAHO-member countries in developing radiological health programs.

The air sampling station locations are shown in figure 5. Analytical techniques were described in the March 1968 issue of *Radiological Health Data and Reports*. The June 1973 air monitoring results from the participating countries are given in table 4.

Figure 5. Pan American Air Sampling Program stations

Table 4. Summary of gross beta radioactivity in Pan American surface air, June 1973

Station location		Number of samples	Gross beta radioactivity (pCi/m³)		
			Maximum	Minimum	Average[a]
Argentina:	Buenos Aires	0			
Bolivia:	La Paz	14	0.02	0.00	0.01
Chile:	Santiago	30	.03	.00	.02
Colombia:	Bogota	16	.01	.00	.00
Ecuador:	Cuenca	6	.00	.00	.00
	Guayaquil	13	.03	.00	.01
	Quito	0			
Guyana:	Georgetown	0			
Jamaica:	Kingston	0			
Peru:	Lima	12	.03	.00	.01
Venezuela:	Caracas	17	.04	.00	.02
West Indies:	Trinidad	0			
Pan American summary		108	0.04	0.00	0.01

[a] The monthly average is calculated by weighting the individual samples with length of sampling period. Values less than 0.005 pCi/m³ are reported and used in averaging as 0.00 pCi/m³.

5. California Air Sampling Program June 1973

Bureau of Radiological Health California State Department of Public Health

The Bureau of Radiological Health of the California State Department of Public Health with the assistance of several cooperating agencies and organizations operates a surveillance system for determining radioactivity in airborne particulates. The air sampling locations are shown in figure 6.

All air samples are sent to the Sanitation and Radiation Laboratory of the State Department of Public Health where they are analyzed for their radioactive content.

Airborne particles are collected by a continu-

Figure 6. California air sampling program stations

ous sampling of air filtered through a 47 millimeter membrane filter, 0.8 micron pore size, using a Gast air pump of about 2 cubic feet per minute capacity, or 81.5 cubic meters per day. Air volumes are measured with a direct reading gas meter. Filters are replaced every 24 hours except on holidays and weekends. The filters are analyzed for gross alpha and beta radioactivity 72 hours after the end of the collection period. The daily samples are then composited into a monthly sample for gamma spectroscopy and an analysis for strontium-89 and strontium-90. Table 5 presents the monthly gross beta radioactivity in air for June 1973. The monthly sample results are presented quarterly.

Table 5. Gross beta radioactivity in California air June 1973

Station location	Number of samples	Gross beta radioactivity (pCi/m^3)		
		Maximum	Minimum	Average
Bakersfield	29	0.79	0.06	0.20
Barstow	30	.53	.05	.14
Berkeley	29	.08	.00	.02
El Centro	8	.38	.05	.11
Eureka	27	.08	.00	.02
Fresno	28	1.02	.04	.19
Los Angeles	28	.08	.00	.04
Redding	28	.19	.02	.06
Sacramento	29	.46	.08	.10
Salinas	29	1.85	.00	.25
San Bernardino	29	.28	.02	.08
San Diego	28	.10	.02	.04
San Luis Obispo	29	.71	.02	.10
Santa Rosa	30	.26	.00	.06
Summary	381	1.85	0.00	0.10

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SECTION IV. OTHER DATA

This section presents results from routine sampling of biological materials and other media not reported in the previous sections. Included here are such data as those obtained from human bone sampling, Alaskan surveillance, and environmental monitoring around nuclear facilities.

Strontium-90 in Human Vertebrae, 1971[1]

Health and Safety Laboratory
U.S. Atomic Energy Commission

Since 1961, the strontium-90 content of human vertebrae has been measured by the Health and Safety Laboratory (HASL). Data obtained from these programs have been used to construct models that attempt to explain the variation of strontium-90 concentrations in bone with age and time. The main purpose of the work is to provide estimates of the radiation dose to man that has resulted from the fallout from nuclear weapons tests. In attempting to construct the models it has become apparent that there are serious gaps in our knowledge of mineral metabolism, especially that of children. The survey data have therefore been used, at times, to gain some insight into the metabolism of strontium by children. This approach is very difficult because of the small numbers of specimens that are available and the absence of an exact knowledge of the diet of the children from whom specimens were obtained. Because it is unlikely that much direct experimental data from tracer studies on children will ever be available, we will be forced to rely on the indirect evidence from survey results to construct our models.

During 1971, 254 specimens of human vertebrae were analyzed, including 56 from children and 37 from adults obtained in New York City and 91 from children and 70 from adults obtained in San Francisco. A summary of the results of strontium-90 determinations is given in table 1.

Table 1. Strontium-90 to calcium ratios in human vertebrae, 1971

Age	Strontium-90 to calcium ratios (pCi ^{90}Sr/g Ca)	
	New York City	San Francisco
0–1 month		0.68 (56)
0–4		.72 (9)
1–2	[a]1.90 (4)	
2–3		1.28 (3)
2–4	2.41 (4)	
5–13		1.65 (2)
1–2 year	3.25 (1)	1.81 (3)
2–3	1.74 (2)	1.16 (1)
3–4	2.65 (2)	1.47 (3)
4–5	2.00 (3)	1.43 (3)
5–6	2.28 (2)	1.74 (2)
6–7	2.30 (1)	.61 (1)
7–8		1.62 (1)
8–9	2.52 (1)	
9–10	1.99 (1)	.53 (2)
10–11		.69 (1)
11–12	2.01 (1)	.81 (1)
13–14	2.42 (3)	
14–15	2.13 (3)	1.46 (1)
15–16	2.30 (2)	
16–17	2.43 (4)	
17–18	1.89 (7)	
18–19	1.90 (11)	.94 (2)
19–20	1.71 (5)	
20–30	1.63 (11)	1.22 (3)
30–40	1.44 (9)	.93 (7)
40–50	1.42 (4)	.69 (10)
50–60	1.15 (4)	.74 (19)
60–70	1.34 (3)	.86 (18)
70–80	1.38 (4)	.87 (11)
80–90		.95 (2)
90–100	1.76 (2)	

[a] Numbers in parenthesis indicate number of samples.

The strontium-90 to calcium ratios for adults are relatively constant, as has previously been observed. The variations about the mean are typical of such survey measurements. The average values and standards deviations for adult vertebrae in 1971 were 1.40 ± .37 pCi/g Ca in New York and .80 ± .35 pCi/g Ca in San Francisco.

The strontium-90 to calcium ratios for children's bones show more variation than the adult

[1] Summarized from Fallout Program Summary Report, HASL-257 (July 1, 1972).

values. Generally higher values are obtained for children than adults, but most values are within a factor of 1½ to 2 of the adult values. The highest value measured in New York vertebrae during 1971 was 3.25 pCi/g Ca for a 1½-year-old child and in San Francisco 2.53 pCi/g Ca for a 5-year-old child.

Bone model

An improved bone model has been formulated to correlate the strontium-90 concentrations in diet and bone. The model as it applied to adult vertebrae is described by the equation:

$$B_n = cD_n + g\sum_{m=0}^{\infty} D_{n-m}e^{-m\lambda} \qquad \ldots (1)$$

where,

B_n = ^{90}Sr concentration in vertebrae in the year n (pCi)

D_n = ^{90}Sr concentration in diet from mid-year in the year n–1 to mid year in the year n (pCi)

c = short-term retention of ^{90}Sr in bone

g = long-term retention of ^{90}Sr in bone

$1 - e^{-\lambda}$ = bone turnover rate plus radioactive decay (yr^{-1})

The formula describes a two compartment model, one compartment associated with short-term retention of strontium on bone surfaces and another compartment in which the strontium is more tightly retained in bone. The parameters c and g are independent and not related to the previously used concept of observed ratio, since retention can also be associated with processes other than new bone formation. The factors c, g, and λ are constant for adults ($\geq$ age 20 years) but are age dependent for children.

Variations of the above bone model were investigated, such as the inclusion of an exponential in the short-term retention term. The best fit in this form, however, was with a very high order exponential, indicating essentially complete turnover of the short-term component during the course of a year.

The above formula for the bone model maintains a desired simplicity and yet gives adequate description of the year-to-year changes in strontium-90 content of bone. The values obtained for the model parameters allow reasonable interpretation.

Strontium-90 in adult vertebrae

The observed strontium-90 concentrations in adult vertebrae are shown in figure 1. Additional approximate values for the earliest years of contamination (1954–59) in New York from the data of Kulp and Schulert (*1*) have also been included. The adult data include only samples from individuals age 20 years or older in 1954, thus representing adult metabolism for the entire contamination period.

A definite decreasing trend in the observed values in adult vertebrae is apparent since 1965, corresponding to decreases in dietary strontium-90 intake. The relatively large standard deviations about the average values preclude extremely accurate determination of the actual decreases and thus the bone turnover rates; however, these are becoming more firmly established as additional years of data accumulate during periods of decreasing strontium-90 levels in diet.

From regression analysis of the measured New York adult diet and vertebrae values through 1970 in the above bone model, one infers a turnover rate of 13 percent per year for adult vertebrae. This value also fits the 1971 results within the standard deviation, but based on least squares criteria from the average observed values, a turnover rate of 18 percent per year is more appropriate for the data through 1971. This latter value also gives the best fit to the San Francisco data through 1971. These best fits to the observed data using the bone model are shown in figure 1.

The model shows peak strontium-90 concentrations in adult vertebrae in 1965, in agreement with observations. Subsequent decreases are achieved with a turnover rate which is reasonable, in view of the remodeling and diffusion processes occurring in bone. The bone model appears to be quite responsive to strontium-90 levels in diet and gives very satisfactory fits to the observed strontium-90 levels in vertebrae.

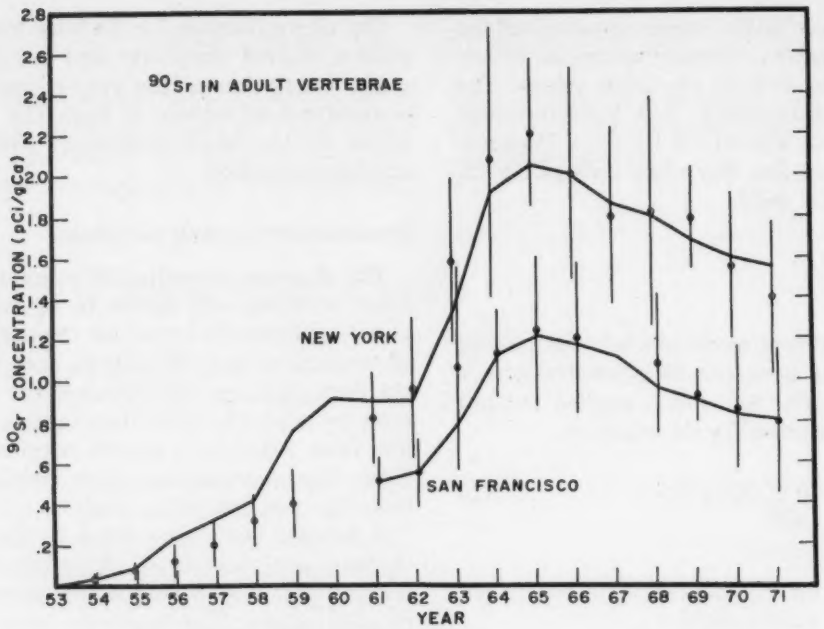

Figure 1. Strontium-90 in adult vertebrae—observations (points with standard deviations) and bone model predictions (solid line)

Strontium-90 in children's bone

The strontium-90 concentration in children's bone can be determined by the formula

$$B_{i,n} = (c_i + g_i) D_{i,n} + [B_{i-1,n-1} - c_{i-1} D_{i-1,n-1}] e^{-\lambda_i}$$

The bone model parameters are defined as before. The subscript i indicates the age dependence.

For the newborn, the strontium-90 concentration can be related empirically to the mother's diet. The strontium-90 to calcium ratio in bone of newborns varies from .1 to .2 times the strontium-90 to calcium ratio in diet of the mother during the year prior to the birth. An average of about .16 is obtained from the survey data.

From the regression results for children, one infers that a one compartment, single exponential model ($c_i = 0$) applies to children under age 8 years. The one compartment formulation of the above model closely corresponds to the previously used Rivera bone model (*2*). The undifferentiated nature of bone of young children and the relatively high turnover rates justify the one compartment treatment.

The turnover rates and relative retention as a function of age are shown in figures 2 and 3. The turnover rates reflect bone growth activity and are highest for the youngest children. Nearly 100 percent per year turnover rate is indicated for the 0–1 year age range. A relatively high turnover rate, about 40 percent, is maintained through the preteenage years. The values then decrease to the adult value.

The relative retention of strontium-90 in bone is the fractional retention of the dietary strontium-90 intake ($c_i + g_i$) per gram of skeletal calcium. The highest efficiency for strontium-90 retention is obtained for the youngest children. Increased efficiency associated with increased growth is also indicated for children in the early teenage years.

The magnitude of the relative retention was determined by assuming that vertebrae behavior is representative of entire skeletal behavior. This assumption becomes less satisfac-

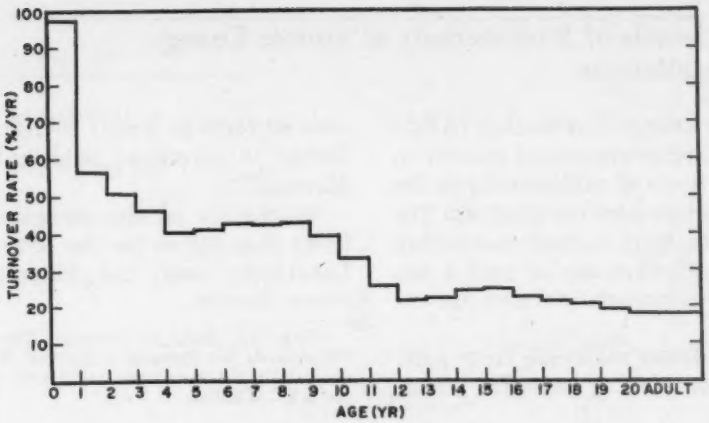

Figure 2. Turnover rates for vertebrae inferred from the two component bone models

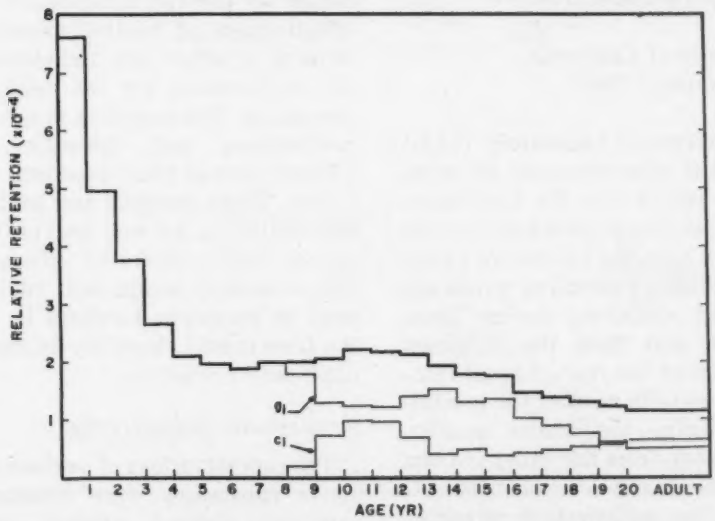

Figure 3. Retention of strontium-90 per gram skeletal calcium (The upper histogram is the total relative retention, c_1 is the short-term component, and g_1 is the long-term component)

tory for older children and adults. Initial estimates of body burden will be high and estimates at later times will be low, assuming less initial retention and slower turnover rates for compact bone. Integral results should be more representative for the entire skeleton, such as the cumulative dose results following a period of strontium-90 intake of 1 year or more.

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(2) RIVERA, J. and J. H. HARLEY. The HASL Bone Program, 1961–1964, HASL—163. U.S. Atomic Energy Commission (August 1965).

Environmental Levels of Radioactivity at Atomic Energy Commission Installations

The U.S. Atomic Energy Commission (AEC) receives from its contractors annual reports on the environmental levels of radioactivity in the vicinity of major Commission installations. The reports include data from routine monitoring programs where operations are of such a nature that plant environmental surveys are required.

Releases of radioactive materials from AEC installations are governed by radiation standards set forth by AEC's Division of Operational Safety in directives published in the "AEC Manual." [1]

Summaries of the environmental radioactivity data follow for the Lawrence Livermore Laboratory and the Shippingport Atomic Power Station.

[1] Title 10, Code to Federal Regulations, Part 20, "Standards for Protection Against Radiation" contains essentially the standards published in Chapter 0524 of the AEC Manual.

1. Lawrence Livermore Laboratory[2] January–December 1971

University of California
Livermore, Calif.

The Lawrence Livermore Laboratory (LLL) (figure 1) is located approximately 50 miles southeast of San Francisco in the Livermore-Amador Valley of California. Shielded from the ocean by the western hills, the Livermore Valley has a warm, dry climate. Prevailing winds are from the west and southwest during April through September, and from the northeast during the remainder of the year. Annual rainfall is about 14 inches with most of the precipitation occurring during the winter months. Surface water drainage from the valley is from east to west through various arroyos, with outflow near Sunol in the southwestern corner of the valley.

Agriculture is the principal activity in the Livermore Valley. Roses, grain, hay, and grapes are the major products. Several cattle and sheep ranches surround the Livermore Laboratory.

The Livermore Laboratory occupies an area of 1 square mile, approximately 3 miles east of the city of Livermore. Livermore and Pleasanton, with a combined population of 45,000 are the populated areas of primary interest to the Livermore site.

[2] Summarized from Environmental Monitoring at Major U.S. Atomic Energy Commission Contractor Sites, Lawrence Livermore Laboratory, January–December 1971.

An environmental sampling program is maintained to provide information regarding the effectiveness of control measures and to determine whether any radiological changes in the environment are the result of laboratory operations. The sampling program includes air particulates, soil, domestic water, sewer effluent, sewage plant products, milk, and vegetation. These samples are analyzed for gross radioactivities as well as for the activity of specific radionuclides of interest. In addition, environmental background radiation is measured at numerous locations in the vicinity of the Livermore Laboratory by means of thermoluminescent detectors.

Atmospheric radioactivity

The concentrations of various airborne radioactive substances were measured at 16 air sampling stations situated throughout the Livermore Valley. Their locations are shown in figures 1 and 2. The six samplers located on the laboratory perimeter use 80 square-inch Whatman 41 filters. The average sampling rate is 25 cfm. The remaining samplers, located offsite, use 36 square-inch HV-70 (cellulose-asbestos) filters and operate at an average flow rate of 4 cfm. These air samplers are situated in such a manner providing reasonable assurance that a significant release of airborne particulate radioactivity from the laboratory would be detected regardless of the local meteorology at the time of the release. Filters are changed weekly during the winter months and twice

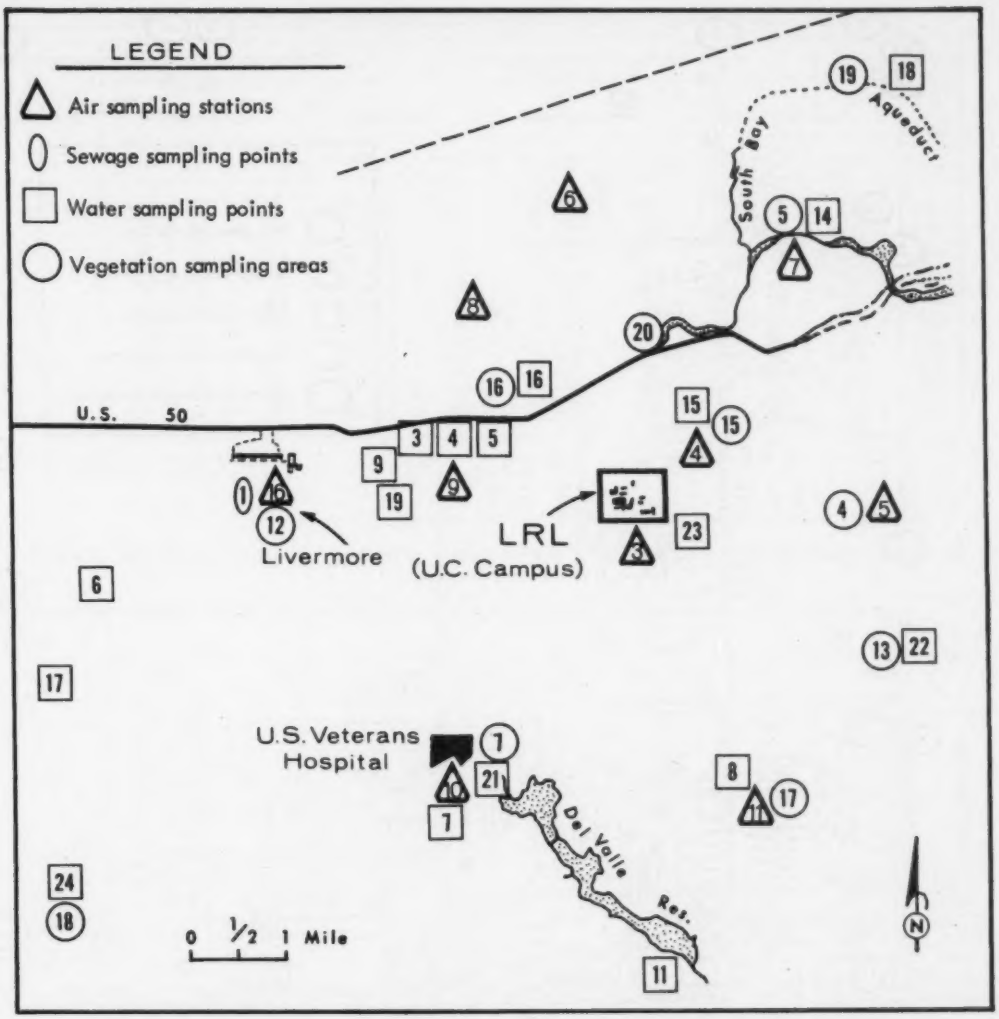

Figure 1. Lawrence Livermore Laboratory offsite environmental sampling locations

weekly during the summer to avoid excessive mass loading. An automatic radiation detection system with gas-flow proportional detectors is used to determine gross alpha and beta activities deposited on the filters after radon decay. The filters are also assayed for gamma-emitting radionuclides by means of a specially designed Ge(Li) detector equipped with a Compton suppression system (*1*).

No gross alpha activity above the 1 fCi/m³ detection limit was observed on the filters. The gross beta activities averaged over 3-month periods and the annual average radioactivities are shown for each sampling location in table 1, where they may be compared with the appropriate AEC standards. A significant fraction of the beta activities deposited on the filters is due to global fallout produced by nuclear weapons tests and by cosmic-ray interactions with the atmosphere. This is shown in table 2 which

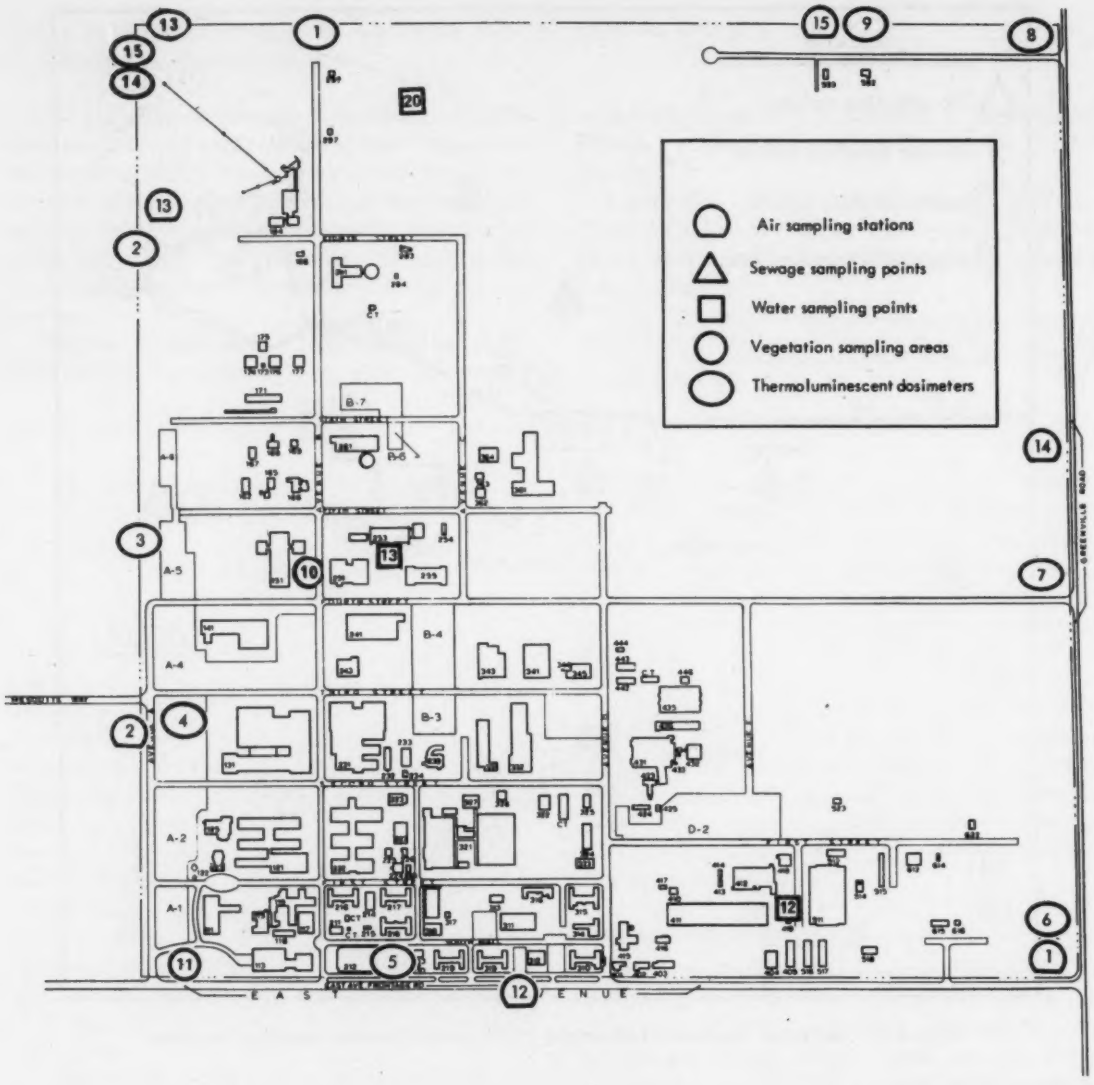

Figure 2. Lawrence Livermore Laboratory onsite environmental sampling locations

lists the activities of the more abundant gamma-emitting radionuclides in monthly composite samples collected by the six laboratory perimeter samplers. These data exhibit the typical spring increase in surface air radioactivity due to the enhanced transport of relatively high activity stratospheric air into the troposphere during this time of year. In addition, the data shows the influence of the French and Chinese atmospheric nuclear weapons tests of 1970 which injected significant quantities of fresh debris into the stratosphere. This is illustrated

Table 1. Airborne particulate activity within the Livermore Valley, January–December 1971

Sampling location [a]	Gross beta radioactivity (pCi/m³)									Percent AEC standard [b]
	January-March		April-June		July-September		October-December		Annual average	
	Maximum	Average	Maximum	Average	Maximum	Average	Maximum	Average		
1	0.45 ± 1%	0.10	0.24±1%	0.18	0.22±4%	0.13	0.090± 2%	0.050	0.12	12
2	.25 ± 1%	.083	.25±1%	.18	.22±1%	.12	.12 ± 5%	.042	.11	11
3	.15 ± 6%	.073	.17±3%	.13	.15±3%	.083	.044± 9%	.027	.080	8
4	.55 ± 2%	.14	.31±2%	.23	.29±2%	.16	.083± 5%	.056	.15	15
5	.34 ± 2%	.084	.26±2%	.16	.22±2%	.11	.040±10%	.026	.095	10
6	.30 ± 2%	.14	.17±3%	.12	.28±2%	.093	.051± 8%	.031	.096	10
7	.051±12%	.031	.16±3%	.12	.15±3%	.075	.051± 8%	.027	.063	6
8	.10 ± 6%	.042	.24±2%	.13	.19±3%	.091	.053± 7%	.023	.072	7
9	.35 ± 2%	.098	.22±3%	.18	.19±3%	.10	.071± 6%	.040	.11	11
10	.18 ± 3%	.096	.24±2%	.13	.13±3%	.067	.050± 8%	.027	.080	8
11	.30 ± 2%	.073	.19±3%	.12	.18±3%	.071	.049± 8%	.024	.072	7
12	.41 ± 1%	.11	.28±1%	.21	.29±2%	.15	.089± 3%	.051	.13	13
13	.38 ± 2%	.10	.28±1%	.19	.22±2%	.13	.15 ± 2%	.053	.12	12
14	.81 ± 1%	.20	.56±1%	.41	.45±2%	.26	.15 ± 2%	.080	.24	24
15	.38 ± 1%	.097	.26±1%	.19	.24±2%	.13	.09 ± 3%	.048	.12	12
16	.53 ± 2%	.11	.24±3%	.16	.22±3%	.10	.064± 6%	.037	.10	10

[a] See figures 1 and 2 for sampling locations.
[b] The AEC standard is 1 pCi/m³.

Table 2. Results of gamma-ray spectral measurements of Livermore Laboratory perimeter air filters January–December 1971

Month (1971)	Concentration (fCi/m³)							
	^{144}Ce	^{141}Ce	^{125}Sb	^{7}Be	^{106}Ru	^{103}Ru	^{137}Cs	^{95}Zr
January	9.9±3%	3.4 ± 8%	0.78±18%	55 ±4%	3.9 ± 8%	3.6±25%	0.98± 9%	3.9 ±4%
February	16 ±3%	4.9 ± 5%	1.3 ±20%	54 ±5%	7.1 ± 6%	6.2±26%	1.2 ±12%	7.6 ±3%
March	47 ±1%	18 ± 2%	2.8 ±11%	83 ±4%	26 ± 2%	21 ± 9%	3.6 ± 5%	36 ±1%
April	62 ±1%	15 ± 2%	3.3 ±15%	88 ±5%	16 ± 3%	28 ±12%	4.6 ± 6%	50 ±1%
May	140 ±1%	20 ± 2%	9.1 ± 1%	130 ±4%	40 ± 9%	48 ± 9%	10 ± 5%	95 ±1%
June	73 ±2%	7.3 ± 6%	3.7 ±22%	57 ±9%	140 ± 5%	32 ±17%	5.0 ±10%	37 ±2%
July	68 ±1%	3.9 ±12%	3.5 ±16%	63 ±6%	11 ± 7%	29 ± 7%	4.6 ± 5%	30 ±2%
August	100 ±1%	2.2 ±19%	6.6 ± 9%	160 ±3%	7.7 ± 8%	43 ± 8%	7.1 ± 5%	84 ±2%
September	56 ±2%	1.8 ±25%	4.0 ±14%	180 ±4%	2.8 ±20%	22 ±15%	4.3 ± 8%	13 ±3%
October	15 ±3%	.64±27%	.97±26%	82 ±4%	.48±42%	10 ±10%	1.3 ±12%	3.3 ±5%
November	34 ±3%	.53±58%	2.5 ±22%	220 ±3%	1.6 ±22%	16 ±17%	2.7 ±11%	5.5 ±5%
December	5.5±4%	5.4 ± 2%	.51±27%	40 ±4%	6.2 ± 3%	1.3±32%	.61±11%	.89±7%
Annual average	52	6.9	3.3	100	22	22	3.8	26
AEC standard [a]	2×10^{3}	5×10^{4}	9×10^{3}	4×10^{7}	3×10^{4}	2×10^{3}	5×10^{3}	1×10^{4}
Percent AEC	0.026	0.00014	0.00037	0.00025	0.00071	0.011	0.00076	0.0026

[a] Assumes the activity is in an insoluble form.

in figure 3 by the zirconium-95 to cesium-137 ratios which increased to a maximum value during the spring, due to the addition of relatively large quantities of zirconium-95 as expected with little or no further addition of fresh debris.

These monthly composite samples were also subjected to plutonium and uranium analyses by dry ashing and complete dissolution of the filters and subsequent radiochemical separation of the elements. The plutonium was isolated by ion-exchange techniques and detected by alpha spectrometry. The isotopic uranium analyses were performed by mass spectrographic methods. The results are provided in table 3. Inspection of the data reveals that the relative activities of plutonium-238 and plutonium-239 approximate those normally observed in global fallout. The decreasing values of the ratio undoubtedly are a result of the addition of fresh plutonium-239 from the recent atmospheric weapons tests, as well as depletion of the plutonium-238 produced by the 1964 SNAP generator burn-up. The uranium-235–uranium-238 ratios approximate the values observed in natural uranium.

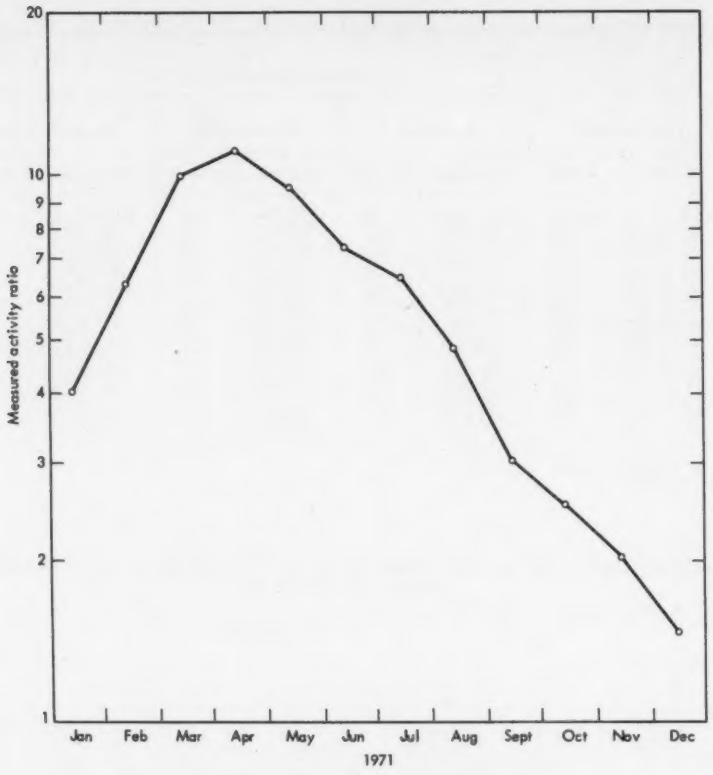

Figure 3. The measured ^{95}Zr–^{137}Cs activity ratios on air filters from LLL perimeter samplers

Table 3. Plutonium and uranium concentrations in Livermore Laboratory perimeter air filters January–December 1971

Month (1971)	Activity (aCi/m³)		$^{238}Pu/^{239}Pu$	Mass (pg/m³)		$^{235}U/^{238}U$
	^{238}Pu	^{239}Pu		^{235}U	^{238}U	
January	3.4 ± 6%	24 ±3%	0.14	0.22 ±2%	47. ±1%	0.0047
February	.83 ± 6%	9.2 ±3%	.09	.070 ±1%	10. ±2%	.0068
March	36 ± 6%	340 ±4%	.11	1.3 ±1%	170. ±1%	.0076
April	9.1 ± 7%	79 ±4%	.12	.25 ±1%	36. ±2%	.0069
May	5.7 ± 7%	110 ±4%	.054	.63 ±1%	100. ±1%	.0063
June	3.4 ±10%	76 ±5%	.045	.33 ±2%	49. ±2%	.0066
July	3.0 ±10%	65 ±5%	.046	.47 ±1%	74. ±2%	.0063
August	2.2 ±10%	47 ±5%	.047	.42 ±1%	62. ±2%	.0066
September	2.1 ±17%	49 ±4%	.043	.26 ±1%	36. ±1%	.0072
October	1.5 ±15%	26 ±6%	.057	.30 ±1%	64. ±1%	.0047
November	1.1 ±14%	27 ±4%	.041	.47 ±1%	47. ±1%	.010
December	.30 ±12%	4.7 ±4%	.064	.047 ±1%	6.7 ±2%	.0070
Annual average	5.7	71		0.40	58.	
AEC standard	1,000,000	1,000,000		1,900,000	15,000,000	
Percent of AEC standard	0.00057	0.0071		0.000021	0.00039	

* Assumes the activity is in an insoluble form.

The calculated annual lung doses to an adult resulting from inhalation of the radionuclides listed in tables 2 and 3 are shown in table 4. These were obtained by using the ICRP Lung Model (*2*) and making the following assumptions:

the radionuclides are present in an insoluble form,

the mean particle activity diameter is 1 micrometer, and

the activities of the radionuclides within the various body organs have obtained equilibrium.

We feel the first two assumptions are reasonable in view of the fact that the activities may be situated in insoluble silicate matrixes within particles that may range in size from 1/10 to several micrometers in diameter. This is the range usually observed in air pollution studies. Also, since global fallout has been with us for upwards of two decades, the third assumption should be valid for most radionuclides since their half-lives in the lung are short relative to the long exposure time. The data in table 4 shows that the resulting inhalation doses are minor with the greatest contribution (2.6 mrem) being due to cerium-144.

Table 4. Inhalation doses resulting from the air concentrations shown in tables 2 and 3

Radionuclide	Calculated annual lung dose (mrem)
Cerium-144	2.6
Cerium-141	.048
Antimony-125	.032
Beryllium-7	.064
Ruthenium-103	.22
Ruthenium-106	.36
Cesium-137	.060
Zirconium-95	.54
Plutonium-238	.012
Plutonium-239	.14
Uranium-235	.0016
Uranium-238	.032

Soil

A soil sampling program is currently underway to determine the surface distribution of various radionuclides that have been deposited within the Livermore Valley as a result of global fallout from atmospheric weapons tests as well as from possible laboratory effluents. A core sampling method was used to obtain the soil samples at various depths down to 20 cm for activity/depth profile studies. Each sample was collected over a surface area ranging between 250 cm^2 to 1,000 cm^2 by combining a minimum of 10 separate cores obtained over an approximate 30 m^2 area.

The samples were thoroughly dried and homogenized before undergoing analyses for the radionuclides of interest. During the initial phases of the program, a minimum of 50 grams of soil were subjected to either the HASL acid leach method (*3*) or a complete dissolution method by various outside contractors for the analysis of plutonium-238, plutonium-239, and strontium-90. Analysis of the leach residues from several samples for quality control purposes indicated that approximately 90 percent of the total plutonium activity in the samples was removed by this leach method. However, because of the possibility of large variations in the chemical and physical state of the plutonium that may appear in the environment, a capability was developed within LLL to completely dissolve 100-gram soil samples by acid dissolution techniques to gain increased analytical sensitivity and sample homogeneity. Standard ion-exchange techniques and alpha-plus-height analyses are used to quantitate the plutonium content of the soil. Gamma spectral analyses were made by placing approximately 300 grams of soil on a Ge(Li) detector equipped with a Compton suppression system. These analyses provided quantitative data regarding the concentrations of cesium-137, cerium-144, zirconium-95, and potassium-40 in Livermore soils.

The results of the analyses are provided in table 5, and the sampling locations are shown in figure 4. The depth profile studies at sampling locations 9, 10, 11, and 15 indicate the artificially produced radionuclides do penetrate appreciably into the soil, probably as a result of leaching or mechanical mixing. Generally, the activity in the 15–20-cm layer is about a factor of 10 less than that in the top 1-cm layer, although wide variations may be observed. As expected, the activity of potassium-40 seems to be distributed fairly homogeneously with depth. Our analytical techniques generally made it possible to detect the activities of plutonium-239, strontium-90, cesium-137, and potassium-40 to a sampling depth of about

Table 5. Activity levels of various radionuclides in soil, January–December 1971

Sampling location	Depth (cm)	Concentration (fCi/g)						^{40}K concentration (pCi/g)
		^{238}Pu	^{239}Pu	^{90}Sr	^{137}Cs	^{95}Zr	^{144}Ce	
1 [a]	0–1				480 ± 6%			2.6 ±16%
	0–24		5.8 ± 5%	58 ± 4%	150 ±13%			2.6 ±16%
			3.5 ± 5%	88 ± 4%				
2 [a]	0–15	22 ± 2%	34 ± 2%	150 ± 7%	290 ±10%			4.8 ±12%
3 [a]	0–15	15 ± 3%	100 ± 3%	140 ± 4%	220 ±12%			4.6 ±12%
4 [a]	0–15	86 ± 3%	300 ± 3%	100 ± 2%	160 ±14%			3.9 ±14%
5 [a]	0–15	270 ± 4%	860 ± 4%	110 ± 7%	190 ±12%			4.6 ±12%
6 [a]	0–15	2.4 ± 5%	9.5 ± 3%	140 ± 7%	160 ±12%			2.7 ±15%
7 [a]	0–15	4.2 ± 3%	13 ± 3%	100 ± 4%	160 ±12%			3.3 ±12%
8	0–15	1.3 ± 5%	8.6 ± 3%	82 ±13%	160 ±12%			5.0 ±10%
9	0–1		10 ±14%	180 ±13%	280 ± 8%	53 ±20%	140 ±34%	13 ± 5%
	1–5		7.7 ±12%	100 ±20%	360 ± 7%			11 ± 6%
	5–10		3.2 ±35%	100 ±20%	130 ±16%			12 ± 7%
	10–15		2.3 ±20%	55 ±25%				13 ± 6%
	15–20		6.4 ±22%	18 ±25%				3.7 ±14%
10	0–1		6.8 ± 5%	160 ± 3%	360 ± 7%	62 ±17%	140 ± 5%	12 ± 6%
	1–5		5.0 ± 5%	100 ± 3%	190 ±11%			14 ± 5%
	5–10		3.3 ± 7%	100 ± 3%	200 ±13%			11 ± 7%
	10–15		1.4 ±12%	50 ± 3%	61 ±29%			11 ± 7%
	15–20		.73 ±13%	17 ± 5%	33 ±43%			13 ± 6%
11	0–1	1.0 ±32%	9.5 ± 7%	200 ±18%	340 ± 8%	47 ±27%	20 ±33%	11 ± 6%
	1–5	.33 ±59%	8.2 ± 5%	130 ±18%	270 ±10%			9.9 ± 8%
	5–10	.77 ±36%	7.7 ± 7%	60 ±21%	96 ±21%			12 ± 7%
	10–15	.95 ±28%	15 ± 6%	50 ±18%	46 ±35%			12 ± 6%
	15–20	.21 ±99%	4.5 ± 8%	10 ±50%				9.9 ± 8%
12	0–1	.68 ±13%	8.2 ± 4%	160 ± 2%	180 ±16%	70 ±24%	460 ±22%	9.9 ±48%
	1–15	.10 ±40%	2.7 ± 4%	67 ± 2%	63 ±24%			1.9 ±20%
13	0–1	.33 ±25%	5.1 ± 4%	150 ± 2%	230 ±11%	130 ±12%	160 ±48%	3.0 ±15%
	1–15	.10 ±40%	2.5 ± 4%	75 ± 2%	87 ±17%			4.1 ±10%
14	0–1	.73 ±10%	7.1 ± 3%	180 ± 2%	230 ±13%	130 ±14%	570 ±16%	1.9 ±26%
	1–15	.063 ±54%	2.8 ± 5%	75 ± 2%	57 ±25%			2.1 ±18%
15	0–1		12 ± 5%	67 ± 6%	190 ±15%	180 ±13%	590 ±19%	1.2 ±41%
	1–5		5.4 ± 6%	55 ± 5%	95 ±17%			3.9 ±12%
	5–10		2.9 ± 7%	63 ± 4%	88 ±19%			3.5 ±14%
	10–15		2.5 ± 8%	53 ± 5%	89 ±21%			3.0 ±17%
	15–20		1.0 ±10%		30 ±46%			4.4 ±12%
16	0–1		7.1 ± 6%	110 ± 3%	180 ±18%	140 ±21%	320 ±38%	5.1 ±16%
	1–20		1.2 ± 8%	48 ± 4%	34 ±34%			5.6 ± 8%
	20–25		.60 ±20%	24 ± 7%				6.6 ± 9%
17	0–1		11 ± 5%	68 ± 3%	210 ±14%	62 ±23%		3.0 ±19%
	1–20		3.6 ±10%	84 ± 5%	87 ±20%			3.6 ±14%
	20–25		1.6 ±15%	27 ± 6%	29 ±56%	140 ±36%		4.4 ±33%
18	0–1		7.3 ± 5%		150 ±16%			3.5 ±15%
	0–20		2.8 ±10%					
	20–25		.90 ±15%		51 ±32%			5.0 ±11%
19	0–1				190 ±14%	84 ±17%	200 ±47%	5.7 ±11%
	0–20		5.0 ± 5%		88 ±25%			5.0 ±13%
20	0–1				1,400 ± 4%	110 ±14%	200 ±44%	4.0 ±14%
	0–20		3.8 ±10%	71 ± 5%	100 ±17%			3.0 ±15%
21	0–1				510 ± 6%	100 ±14%	300 ±26%	4.1 ±14%
	0–20		2.8 ±15%	52 ± 9%	60 ±26%			3.4 ±14%
22	0–1				1,000 ± 6%	130 ±18%	490 ±25%	3.3 ±23%
	0–20		7.8 ± 5%		190 ±14%			4.6 ±14%
23	0–1				140 ±19%	210 ±37%		4.0 ±16%
	0–20		3.0 ±15%	80 ± 9%	85 ±25%			3.5 ±16%
24	0–1				560 ± 7%	89 ±16%	290 ±30%	4.1 ±15%
	0–20		8.7 ± 5%		97 ±26%			3.7 ±18%
25	0–1				220 ±11%	76 ±15%	200 ±38%	4.4 ±12%
	0–20		1.9 ±20%	70 ± 8%	49 ±28%			3.2 ±13%
26	0–1				180 ±11%	28 ±31%		3.8 ±13%
	0–20		4.4 ±10%		150 ±15%			2.7 ±18%
27	0–1				480 ± 7%	43 ±25%		5.7 ±11%
	0–20		3.4 ±10%		110 ±22%	140 ±35%		3.2 ±18%
28	0–1				290 ±15%	99 ±21%		7.7 ±10%
	0–20		3.1 ±10%		70 ±27%			3.5 ±15%
29	0–1				420 ±12%			4.1 ±20%
	0–20		.12 ± 5%		110 ±18%			3.9 ±14%
30	0–1				730 ± 6%			.89 ±40%
	0–20		5.9 ± 5%	75 ± 5%	94 ±20%			.92 ±40%
31	0–1				210 ±11%			3.5 ±13%
	0–20		3.4 ±15%	37 ±10%	92 ±16%			4.2 ±10%
32	0–1				280 ±10%	140 ±41%		3.9 ±14%
	0–20		2.5 ±15%	38 ± 7%	46 ±30%			4.7 ±10%
33	0–1				410 ± 7%	41 ±25%	200 ±37%	2.6 ±15%
	0–20		1.0 ±10%	66 ± 6%	90 ±18%			3.3 ±13%
34	0–1				92 ±21%	35 ±33%		6.1 ±10%
	0–20		1.1 ±10%	75 ± 3%	100 ±20%			4.2 ±14%
35	0–1				420 ± 7%	77 ±17%		4.3 ±11%
	0–20		6.5 ± 5%	45 ± 7%	160 ±15%			4.7 ±13%
36	0–1				150 ±13%	42 ±28%		5.6 ± 9%
	0–20		3.4 ± 5%	69 ± 6%	75 ±26%			4.8 ±13%
37	0–1				260 ±12%	35 ±46%	220 ±45%	3.0 ±17%
	0–20		4.5 ± 5%	61 ± 6%	95 ±19%			3.3 ±14%
38	0–1				330 ±10%	87 ±30%		6.0 ±11%
	0–20		2.1 ±10%		75 ±28%			5.6 ±12%

See footnotes at end of table.

Table 5. Activity levels of various radionuclides in soil, January–December 1971—continued

Sampling location	Depth (cm)	Concentration (fCi/g)						^{40}K concentration (pCi/g)
		^{238}Pu	^{239}Pu	^{90}Sr	^{137}Cs	^{95}Zr	^{144}Ce	
39	0–5		12 ± 5%	110±16%	200±13%			11 ± 7%
	5–10		7.8 ±10%	82±18%	96±21%			13 ± 6%
	10–15		5.5 ±10%	64±18%	94±24%			9.6 ± 8%
40	0–24		3.5 ± 5%	88± 4%				
41	0–1				140±14%	66±34%		
	0–24		200 ± 5%		42±40%			
42	0–1		4.3 ±10%		130±14%	20±45%		
	0–24		2.5 ±10%					
43	0–1				480± 8%		290±30%	
	0–24		5.5 ± 5%					
44	0–1		3.0 ±10%					
	0–24		3.2 ± 5%					
45	0–5		360 ± 5%					
	5–10		12 ± 5%					
	10–15		9.0 ± 5%					
	15–25		1.2 ± 5%					
46	0–25		2.6 ± 5%	67± 5%				
47	0–25		1.8 ± 6%	61± 9%				
48	0–25		2.2 ± 7%	62± 6%				
49	0–25		2.5 ± 5%	68± 5%				
50	0–25	.18 ±14%	2.8 ± 4%	92± 4%				
51	0–1	1.2 ± 8%	30 ± 4%					
	1–25	2.6 ± 7%	100 ± 3%					
52	0–1	.72 ± 8%	59 ± 8%					
	1–25	3.5 ± 9%	98 ± 5%					
53	0–1	1.8 ± 8%	16 ± 4%					
	1–25	13 ± 4%	220 ± 3%					
54	0–1	1.6 ± 7%	18 ± 4%					
	1–25	14 ± 5%	420 ± 4%					
55	0–30	.14 ±15%	3.5 ± 4%					
56	0–25	.59 ±11%	9.3 ± 4%					
57	0–25	.14 ±15%	2.1 ± 4%					
58	0–25	.23 ±12%	7.6 ± 3%					
59	0–25	.14 ±14%	2.6 ± 4%					

• Sample locations 1 through 7 are located onsite. All others are offsite.

20–30 cm, while zirconium-95 and cerium-144 could only be detected in the top 1-cm layer.

The resulting deposition values are shown in table 6. Most of the plutonium-239 deposition levels are of the order of 1 mCi/km^2, but some locations indicate values that are appreciably higher. For instance, the elevated levels shown at onsite locations 1 to 7 are due to their close proximity to the area being used for solar evaporation of low-level radioactive waste liquids. These levels are undoubtedly due to a number of low-level spills that occurred in this area several years ago in connection with the solar evaporation operation. This contamination, however, has not spread offsite as indicated by the plutonium levels observed at loca-

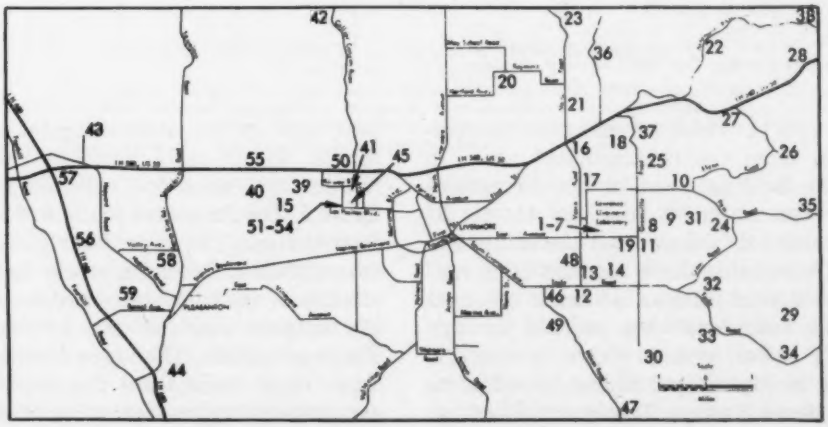

Figure 4. Livermore Valley soil sampling locations

Table 6. Deposition levels of various radionuclides in soil, Livermore, January–December 1971

Sampling location	Concentration (mCi/km²)					
	^{238}Pu	^{239}Pu	^{90}Sr	^{137}Cs	^{95}Zr	^{144}Ce
1 [a]		1.7	17	36		
2 [a]	4.8	7.5	33	64		
3 [a]	8.4	22	31	49		
4 [a]	18	63	21	34		
5 [a]	56	180	23	39		
6 [a]	0.65	2.6	38	44		
7 [a]	1.2	3.7	29	33		
8	.29	1.9	18	36		
9		1.1	17	15	0.71	1.9
10		.76	20	36	.84	1.9
11	.16	2.6	19	30	.63	.27
12	.028	.65	16	15	.70	4.4
13	.024	.57	17	20	1.5	1.9
14	.018	.65	17	14	1.4	6.3
15		.55	11	20	1.5	5.0
16		.49	18	12	1.9	4.3
17		1.25	26	28		
18		.90				
19		1.4		25	1.1	2.6
20		.93	18	25	1.1	2.0
21		.73	13	15	1.2	3.6
22		1.7		40	1.0	3.9
23		.76	20	21	1.5	2.2
24		2.1		23	.98	3.3
25		.48	18	13	.91	2.3
26		1.14		40	.36	
27		.82		26	.53	
28		.80		19	1.3	
29		3.0		28		
30		1.61	21	26		
31		.97	11	27		
32		.71	11	13		
33		.32	18	23	.51	2.5
34		.26	18	24	.42	
35		1.7	12	42	.97	
36		.89	18	20	.57	
37		1.3	17	27	.42	2.7
38		.57		20	1.1	
39		1.8	18	27		
40		1.1	27			
41		60		12	0.83	
42		0.81				
43		1.9				
44		1.2				
45		27				
46		.91	23			
47		.65	22			
48		.76	22			
49		.87	24			
50		.98	33			
51	0.88	34				
52	1.2	33				
53	4.6	78				
54	5.4	162				
55	.057	1.5				
56	.19	3.0				
57	.044	.68				
58	.079	2.7				
59	.047	.9				

[a] Sample locations 1 through 7 are onsite. All others are offsite.

tions 8, 9, and 11 which are situated immediately offsite from the contaminated area. In addition, the holding pond at the Livermore Sewage Treatment Plant, locations 41, 45, 51 through 54 also indicate elevated plutonium-239 activities. These values have resulted from routine and accidental releases of small amounts of plutonium over long time periods through the sanitary sewer system which carries the laboratory's biological and industrial effluents to the Livermore Sewage Treatment Plant.

In order to gain a better perspective of the contribution that the laboratory operations have had on the environmental levels of plutonium within the Livermore Valley, the plutonium-239 deposition values were plotted in figure 5. The data were found to fit two separate distributions. The upper distribution represents data obtained from the onsite locations in the vicinity of the solar evaporation area and from the holding pond at the Livermore Sewage Treatment Plant. The lower distribution, on the other hand, represents the remainder of the data obtained from areas where the laboratory's contribution has been minimal, if any, and therefore represents predominantly the contri-

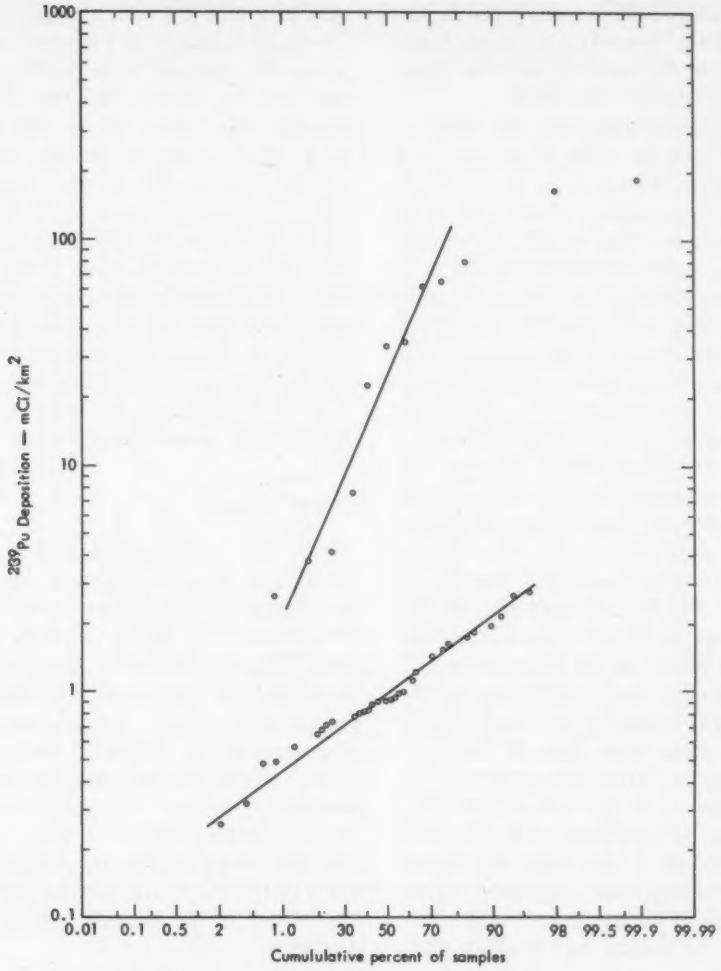

Figure 5. Distribution of plutonium-239 deposition values in Livermore Valley soils
(The upper distribution represents data obtained from onsite locations and from one of the holding ponds at the Livermore sewage treatment plant. The lower distribution represents data obtained from areas where the laboratory's contribution has been minimal)

bution due to global fallout from atmospheric weapons test. This distribution exhibits a mean value of 1 mCi/km², which is almost a factor of 2 less than the mean value obtained from the data of Hardy and Krey (*4*). Their measurements of global fallout-produced plutonium-239 deposition levels at 13 sites throughout the United States ranged from 0.7–2.4 mCi/km². Since most of the global fallout contribution has been by wet deposition, this factor of 2 difference is quite reasonable in view of the Livermore Valley's low annual rainfall of about 14 inches. Likewise, the median cesium-137 deposition level of 26 mCi/km² is about a factor of 3 below the median deposition level that one may derive from the cesium-137 exposure rates in air measured by Lowder and McLaughlin (*5*) at many locations throughout hte United States. The activities of zirconium-95 and cerium-144 are appreciably lower than that of cesium-137 and strontium-90 primarily due to their relatively short half-lives. One would expect their activi-

ties to be mainly due to the recent French and Chinese atmospheric nuclear weapons tests. Thus, the laboratory's contribution to these fission product activities is negligible.

The samples collected onsite in the vicinity of the area being used for solar evaporation of low level radioactive liquids were, in addition, subjected to isotopic uranium analysis by mass spectrographic methods. The results are shown in table 7. The total uranium concentrations are less than the global average of about 4 μg/g and the uranium-235/uranium-238 ratio approximates that in natural uranium, indicating that the solar evaporation operation has not contributed any measurable uranium activity to the environment in this particular area.

Environmental radiation levels due to the gamma-emitting radionuclides distributed in the soil may be inferred from these measurements by using the data of Beck and de Planque (*6*). Detailed calculations have not been completed at this time, but preliminary results indicate that the mean exposure rate in air due to the cesium-137 activity in the soil at a height of 1 meter above the ground within the Livermore Valley is approximately 0.1 μR/h (0.88 mR/yr). The exposure rates due to the zirconium-95 and cerium-144 activities in the soil are insignificant relative to that of cesium-137. By using the data of Wollenberg, et al (*7*) and the data in tables 5 and 7, one may determine the mean natural background exposure rates due to the activities of potassium-40 and uranium-238 series in the soil to be 0.7 μR/h (6.2 mR/yr) and 1.4 μR/h (12.3 mR/yr), respectively, at a height of 1 meter above the ground. Thus, the natural contribution to the exposure rate due to gamma emitters in the soil is far greater than that due to the artificially produced radionuclides. To determine the environmental impact due to the elevated plutonium deposition levels is very difficult. For these particular sites, the primary concern to man is that due to resuspension of the plutonium and subsequent inhalation. Since resuspension factors vary over many orders of magnitude, it is difficult to calculate a meaningful expected airborne concentration. However, we anticipate that these airborne concentrations will not be significantly above background levels.

Sewer effluent

The low level radioactive wastes from the laboratory are discharged into the City of Livermore sanitary sewer system. This effluent is processed at the Livermore Sewage Treatment Plant where the liquid and sludge are separated on entering the plant. The sludge passes into one of two digesters where it is broken down by bacterial action. Methane gas is evolved and burned, and the remaining sludge is released to large sludge ponds and retained for subsequent use as a soil conditioner. The purified water is used for irrigating the Livermore Golf Course and nearby agricultural land; the excess is discharged into the Los Positas Arroyo.

Table 7. Concentrations of uranium in soils, Livermore Laboratory, January–December 1971

Sampling location	Depth (cm)	^{234}U (pg/g)	^{235}U (ng/g)	^{238}U (μg/g)	Total uranium (μg/g)	$^{235}U/^{238}U$ *
2	0–15	114 ± 4%	13.4 ±1%	1.86±2%	1.87±2%	0.0072
3	0–15	115 ± 5%	13.5 ±1%	1.88±2%	1.90±2%	.0072
4	0–15	110 ± 3%	13.6 ±1%	1.88±2%	1.90±2%	.0072
5	0–15	150 ± 1%	14.8 ±1%	2.05±2%	2.07±2%	.0072
6	0–15	114 ± 9%	12.0 ±2%	1.69±2%	1.70±2%	.0071
7	0–15	100 ± 2%	12.5 ±2%	1.75±2%	1.76±2%	.0071
8	0–15	103 ± 2%	12.1 ±1%	1.69±2%	1.71±2%	.0072
11	0–1	72.5± 1%	9.70±1%	1.36±2%	1.37±2%	.0071
	1–5	85.0± 1%	11.2 ±1%	1.55±2%	1.56±2%	.0072
	5–10	70.0±14%	8.80±1%	1.22±2%	1.23±2%	.0072
	10–15	80.0± 3%	10.6 ±1%	1.48±1%	1.49±2%	.0072
	15–20	81.0± 4%	11.0 ±4%	1.53±2%	1.54±2%	.0072

* The $^{235}U/^{238}U$ ratio in natural uranium is 0.0072.

Table 8. Livermore sewage treatment plant sampling results, January–December 1971

Month (1971)	Gross alpha activity (pCi/liter)						
	Digesters		Aeration tank		Effluent		
	High	Average	High	Average	High	Average	Percent AEC standard [a]
January	380 ±20%	250	57 ±19%	43	22 ±50%	13	13
February	230 ±24%	160	29 ±26%	27	80 ±50%	26	26
March	180 ±42%	150	49 ±41%	39	32 ±50%	14	14
April	190 ±23%	190	31 ±27%	29	11 ±50%	54	54
May	350 ±20%	210	74 ±22%	49	27 ±50%	11	11
June	510 ±13%	280	52 ±21%	48	5.6 ±50%	2.7	2.7
July	300 ±16%	220	320 ±13%	140	7.4 ±50%	3.3	3.3
August	440 ±19%	260	73 ±19%	45	13 ±50%	5.9	5.9
September	530 ±24%	280	99 ±15%	61	13 ±50%	5.3	5.3
October	220 ±21%	110	66 ±17%	50	11 ±50%	5.9	5.9
November	440 ±21%	220	42 ±26%	30	14 ±50%	8.2	8.2
December	260 ±22%	180	80 ±18%	47	11 ±50%	6.5	6.5
Average		208		51		13	13
	Gross beta activity (pCi/liter)						
January	1,400 ±5%	530	60 ±4%	49	48 ±15%	17	17
February	970 ±4%	360	45 ±5%	27	37 ±80%	19	19
March	1,100 ±6%	580	120 ±5%	71	88 ±14%	35	35
April	1,000 ±4%	530	84 ±5%	48	40 ± 9%	17	17
May	340 ±8%	280	52 ±5%	37	31 ±17%	17	17
June	1,000 ±4%	390	41 ±5%	36	17 ±24%	15	15
July	400 ±7%	290	55 ±4%	36	19 ±22%	14	14
August	600 ±7%	380	76 ±4%	52	19 ±22%	14	14
September	4,300 ±2%	1,000	55 ±4%	47	20 ±20%	15	15
October	420 ±8%	250	48 ±5%	43	44 ±13%	19	19
November	400 ±8%	280	38 ±6%	35	24 ±19%	17	17
December	1,000 ±4%	380	58 ±4%	48	43 ±13%	22	22
Annual average		440		44		18	18

Month (1971)	Tritium activity (nCi/liter)			Strontium-90 activity (pCi/liter)	
	Effluent			Effluent	
	High	Average	Percent AEC standard [c]	Average	Percent AEC standard [d]
January	14 ± 5%	11	0.37	0.5 ±50%	0.17
February	4.1 ±50%	3.6	.12	1.5 ±20%	.50
March	240 ± 3%	43	1.43	.6 ±21%	.20
April	8.0 ±14%	4.2	.14	1.6 ±18%	.20
May	340 ± 2%	56	1.87	.4 ±50%	.13
June	1.8 ±50%	1.7	.06	.6 ±50%	.20
July	15 ± 5%	6.3	.21	.5 ±50%	.17
August	3.9 ±16%	2.2	.07	2.3 ±50%	.77
September	110 ± %	15	.50	1.3 ±25%	.43
October	20 ± 4%	5.8	.19	1.1 ±38%	.37
November	12 ± 6%	3.5	.12	3.3 ±30%	1.10
December	12 ± 6%	3.9	.13	.9 ±21%	.30
Annual average		13	.43	1.2 ±42%	

[a] AEC standard (alpha activity) = 100 pCi/liter.
[b] AEC standard (beta activity) = 100 pCi/liter.
[c] AEC standard (HTO) = 3,000 nCi/liter.
[d] AEC standard (^{90}Sr) = 300 pCi/liter.

Weekly samples were collected from each digester, the aeration tank and the liquid effluent discharged from the plant in order to determine if any significant buildup of radioactivity occurred within the plant. These samples were subjected to gross alpha and beta analyses by complete dissolution, electrolytic deposition and direct proportional counting. The tritium analyses were performed by subjecting 1 ml of each sample to direct liquid scintillation counting. In addition, a monthly composite sample of the effluent was analyzed for strontium-90 by radiochemical separation and beta counting. The concentrations observed during 1971 averaged over 1 month periods are given in table 8. Most of the gross alpha and

gross beta activities are associated with the sludge present in the effluent. Thus, samples obtained from the digesters show the highest activities with the expected attendant decrease in activity as the relatively purified liquid passes through the aeration tank and is finally released from the plant.

Water

Monthly samples were collected from various water sources in the Livermore Valley. These samples were analyzed for gross alpha and gross beta activities by techniques similar to those used for sewage effluent samples. No sample showed an alpha activity above the limit of detection of 1.2 pCi/liter. Quarterly averages for beta activities are given in table 9. Locations 7, 14 through 18, and 21 through 24 represent surface sources such as ponds, creeks, reservoirs, and aqueducts. Livermore rainfall is sampled at location 20. The remainder of the locations are domestic water sources. The activities are reasonably homogeneous with the highest value occurring in the rainfall sample collected over a 3-month period.

The samples collected during the first 6 months of 1971 were analyzed for tritium activity by direct scintillation counting. The maximum activity was 11 nCi/liter ± 8 percent with an average value of 4.0 nCi/liter (the limit of detection) which is 0.1 percent of the offsite AEC standard of 3 μCi/liter. Because of these low radioactivities, the samples collected during the last 6 months were vacuum distilled and electrolytically enriched before scintillation counting. The results of these analyses are shown in table 10. Inspection of the data indicates that the samples also exhibit rather uniform tritium concentrations that are well below the AEC standards. The table also includes an estimate of the dose that may be delivered to an adult consuming water containing the listed tritium concentrations. The doses, which are typically less than 0.1 mrem, are based upon a daily water consumption of 1 liter per day (*8*) and the model of Anspaugh, *et al.* (*9*).

Vegetation

Vegetation samples (usually native grasses) were collected from nine locations in the Livermore Valley during January, April, and May. The samples were dried in ambient air for about a week and then pressed into 5-inch diameter and 1-inch thick pellets weighing approximately 200 grams. The pellets were analyzed for various gamma-emitting radionuclides by placing them between two 8- by 4-inch NaI(Tl) crystals. A portion of each sample was also freeze dried and the collected water was analyzed for tritium activity by direct scintillation counting. These techniques were changed in the middle of the year after the development of improved analytical facilities. During the months of August, October, and

Table 9. Gross beta radioactivity in Livermore water samples, January–December 1971

January-March		April-June		July-September		October-December	
Location	Activity (pCi/liter)	Location	Activity (pCi/liter)	Location	Activity (pCi/liter)	Location	Activity (pCi/liter)
1	—	11	7.4	11	3.7	11	3.0
2	—	12	8.9	12	3.3	12	2.0
3	2.9	13	8.2	13	3.4	13	2.0
4	2.2	14	7.0	14	—	14	—
5	2.7	15	4.9	15	2.3	15	2.9
6	2.0	16	12.3	16	7.1	16	5.9
7	3.1	17	4.9	17	6.0	17	5.2
8	2.4	18	9.2	18	3.7	18	3.1
9	2.6	19	3.4	19	2.1	19	2.9
10	—	20	23.7	20	—	20	—
11	—	21	4.7	21	2.0	21	3.0
12	4.3	22	9.1	22	3.2	22	7.6
13	3.6			23	2.2	23	2.4
				24	4.8	24	6.1
Average	2.9		7.8		4.0		3.8
Percent AEC standard*	10		26		13		13

* AEC standard (beta activity) = 30 pCi/liter.

Table 10. Tritium activities in Livermore water samples collected during July–December 1971

Sampling location	Concentration (pCi/liter)		Percent AEC standard[a]	Calculated annual adult whole body radiation dose (mrem)
	Maximum	Average		
11	320 ±6%	260	0.0086	0.010
15	320 ±7%	280	.0093	.011
16	1,100 ±4%	870	.029	.035
17	210 ±8%	[b]200	.0067	.0080
18	—	[b]270	.0090	.011
19	170 ±8%	[b]160	.0053	.0065
20	—	[b]810	.027	.032
21	—	[b]270	.0090	.011
22	410 ±6%	[b]400	.013	.016
23	720 ±5%	[b]370	.012	.015
24	1,200 ±4%	[b]600	.020	.024
Average		410	0.014	0.016

[a] AEC standard (HTO) = 3×10^6 pCi/liter.
[b] Single sample collected at these locations.

November, samples were collected from 13 locations in the Livermore Valley. The samples collected during a particular month were dried and composited. A 100-gram portion of the composite sample was counted on the Ge(Li) detector used for analyzing the airborne particulate samples. The tritium concentrations in the water, obtained by freeze drying these samples, were determined by electrolytic enrichment and subsequent scintillation counting.

The results of the gamma spectral analyses are shown in table 11. These activities exhibit their highest values during the spring months; this is undoubtedly due to the higher ambient atmospheric concentrations during this time of year. Using these data, one may calculate the annual radiation dose received by man from direct ingestion of these radionuclides assuming the observed activities are typical of those in edible vegetation. The calculated adult whole body or critical organ doses due to the gamma emitters shown in table 11, are based upon an adult consumption of 400 grams per day vegetation (*8*) with a moisture content of 80 percent and the data of Ng, *et al.* (*10*) regarding the dose received per unit of radioactivity consumed under equilibrium conditions. With the exception of global fallout-produced cerium-144 and natural potassium-40 activities, these radionuclides deliver appreciably less than 1 mrem/yr to the whole body or critical organ as a result of direct ingestion of edible vegetation. The cerium-144 and potassium-40 activities, on the other hand, may easily deliver up to 10 mrem/yr to the lower large intestine and whole body, respectively.

The results of the tritium analyses are shown in tables 11 and 12. The data show significant variation from one location to another which may be caused by laboratory operations.

From figure 2, one may expect the effect of the laboratory's operation on the environment to be minimal at locations 4, 7, 13, 17, 18, and 19 because the prevailing wind is from the southwest. Samples collected at these locations exhibit tritium values ranging from 160 to 450 pCi/liter, which may be considered environmental background levels. However, locations 10 and 11 are onsite and locations 5, 15, 16, and 20, which show elevated levels, are situated in a generally downwind direction from the laboratory, thus exposing the vegetation in these areas to the low level gaseous effluent released routinely from the Gaseous Chemistry Building. The samples collected at location 12 represent grass that has been watered by the liquid effluent from the Livermore Sewage Treatment Plant. The resulting whole body doses to an adult, shown in the tables, were derived from the model of Anspaugh, *et al.* (*9*). These are also based upon the direct daily consumption of 400 grams of vegetation (*8*). This mass of vegetation, however, is assumed to be equivalent to the same mass of water containing the tritium concentrations shown in the tables under equilibrium conditions. One may readily observe that, in spite of the slightly elevated levels, the calculated annual whole body doses are still very small.

Milk

During the first 8 months of 1971, milk samples were collected each month from two dairies, one located in the Livermore Valley about 6 miles west of the laboratory and the other in the San Joaquin Valley about 6 miles southwest of Tracy. In August 1971, the Livermore Valley dairy ceased operations. Since no other was available, milk sampling was restricted to the San Joaquin Valley dairy during the rest of the year. Before analysis, the samples were concentrated by means of a vacuum-operated, foam-entrainment evaporator so that about 9

Table 11. Average radionuclide activities in Livermore vegetation samples collected during 1971

Radioactivity in samples collected	Average activity (pCi/g)	Calculated annual dose ingestion (mrem)	Critical organ
During Jan., Apr. and May:			
^{137}Cs	0.18	0.32	Whole body
^{144}Ce	1.4	11.0	Lower large intestine
^{95}Zr–^{95}Nb	.63	—	
^{7}Be	1.8	.090	Lower large intestine
^{3}H	25 nCi/l	.40	Whole body
During Aug., Oct. and Nov:			
^{137}Cs	.08	.14	Whole body
^{103}Ru	.13	.14	Lower large intestine
^{144}Ce	.59	4.6	Lower large intestine
^{95}Zr	.053	.13	Lower large intestine
^{7}Be	2.1	.10	Lower large intestine
^{40}K	3.0	4.2	Whole body

Table 12. Tritium activities in Livermore vegetation samples collected in August, October, and November 1971

Sample location *	Tritium activities (nCi/liter)		Calculated annual whole body dose (mrem)
	Maximum	Average	
4	0.46±51%	0.33	0.005
5	9.8 ± 3%	4.7	.08
7	.61±31%	.45	.007
10	28 ± 2%	11	.2
11	120 ± 1%	39	.6
12	3.3 ± 7%	1.8	.03
13	.44±44%	.30	.005
15	1.7 ±12%	1.4	.02
16	9.0 ± 4%	3.5	.06
17	.17±103%	.16	.003
18	.28±65%	.28	.005
19	.26±68%	.22	.003
20	6.8 ± 4%	6.4	.1
Average		5.3	0.08

* The sample locations are shown in figure 1.

liters of whole milk were condensed to 2 liters. The resulting samples were subjected to gamma spectral analyses by inserting them between two 8- by 4-inch NaI (Tl) crystals. In addition, each sample was analyzed for tritium activity by counting 1 milliliter of the distillate directly in a standard liquid scintillation detector. The activities of cesium-137, cerium-144, tritium, and potassium-40 are shown in table 13. Also shown are the calculated annual adult whole body or critical organ doses delivered to man via the milk pathway. These calculations are based upon a daily intake of 260 g/day (*8*) and the models previously referenced. As expected, the only significant dose to an individual is that from potassium-40.

Accidental release of tritium gas

Continuous air sampling is maintained on the stack effluent from the Gaseous Chemistry Building. On April 12, 1971, an accidental release of 240 Ci of tritium occurred. Because the tritium was expected to be in the vapor

Table 13. Radionuclide activity observed in milk samples collected January–December 1971

Location, date collected, and radionuclide	Concentration (pCi/liter)		Calculated annual adult radiation dose (mrem)	Critical organ
	Maximum	Average		
Livermore Valley Dairy				
January–August:				
Cesium-137	9.1	4.5	0.026	Whole body
Cerium-144	19	11	.23	Lower large intestine
Tritium	100,000	17,000	.054	Whole body
San Joaquin Valley Dairy				
January–August:				
Cesium-137	5.6	3.8	.022	Whole body
Cerium-144	56	13	.14	Lower large intestine
Tritium	6,700	430	.0013	Whole body
September–December:				
Cesium-137	3.9	2.7	.016	Whole body
Cerium-144	26	18	.46	Lower large intestine
Tritium	1,300	620	.0019	Whole body
Potassium-40	1,300	1,200	5.4	Whole body

form, an extensive sampling program was conducted to evaluate the impact of the release on the environment. Vegetation, atmospheric water vapor, and water samples were collected and analyzed for tritium activity. The vegetation samples were freeze-dried and the collected water was subjected to scintillation counting. Other samples were counted directly in the same manner. Detectable activities were observed in some offsite vegetation and water vapor samples. The maximum activity in vegetation samples was 160 nCi/liter with the average activity of all the samples being $\leq$ 25 nCi/liter. The atmospheric water vapor samples indicated a maximum activity of 5.9 nCi/m^3 and an average value of 2 nCi/m^3.

A hazards analysis was performed in order to determine the potential exposure to a hypothetical individual standing downwind at the point of maximum surface air concentration during cloud passage. Using standard atmospheric diffusion calculations and tritium uptake estimates, one may calculate that it would have been possible for this individual to have received a maximum of 1.5 mrem during cloud passage. An estimate was also made of the maximum potential dose that a child could have received from drinking milk produced by cows grazing on vegetation contaminated with tritium at the maximum observed concentration. Using the model of Anspaugh, *et al.* (*9*), the maximum potential dose via this pathway to an infant would have been 0.18 mrem and that to an adult, 0.03 mrem.

Environmental radiation measurements

Environmental radiation background measurements were made at 12 laboratory perimeter locations shown in figure 2, and at 40 offsite locations in the immediate vicinity of the laboratory. These measurements were made with CaF:Dy (TLD-200) thermoluminescent dosimeters placed at a height of 1 meter above the ground. Exposure periods were usually 3 months. The resulting exposure rates reflect the sum of terrestrial and cosmic radiation sources. Based on past experience, the exposure rates in the Livermore Valley due to terrestrial sources varied between 4 and 7 μR/h depending upon the location, while that due to cosmic radiation, according to the data of Lowder and Beck (*11*), is approximately 4 μR/h. Table 14 shows the exposure rates obtained at the perimeter locations during three periods in 1971. This data is also expressed as projected annual millirem dose rates (1 μR/h = 7.612 mrem per year). Inspection of the data revealed that location 5 during the April–June period and locations 13, 14, and 15 during the November–December period showed above average exposure rates. Location 5 is adjacent to a cyclotron building and locations 13, 14, and 15 are near a linear accelerator facility.

Site 300

Atmospheric radioactivity

The concentrations of various particulate airborne radioactive substances were measured

Table 14. Environmental radiation background measurements at the Livermore Laboratory perimeter, 1971

Location	April-June		August-November		November-December	
	(μR/h)	(mrem/year)	(μR/h)	(mrem/year)	(μR/h)	(mrem/year)
1	10.8	78	9.1	69	11.1	85
2	9.6	73	9.4	72	11.9	91
3	11.1	85	10.4	79	11.7	88
4	9.6	73	9.5	72	11.1	85
5	14.4	110	10.4	79	8.9	68
6	9.6	73	—	—	9.3	71
7	7.9	60	8.7	66	—	—
8	8.8	67	8.0	61	9.5	72
9	7.9	60	8.1	62	9.5	72
13	—	—	10.5	80	12.1	92
14	—	—	9.1	69	12.3	94
15	—	—	11.3	86	13.2	100
Average	9.9	75	9.5	72	11.0	84

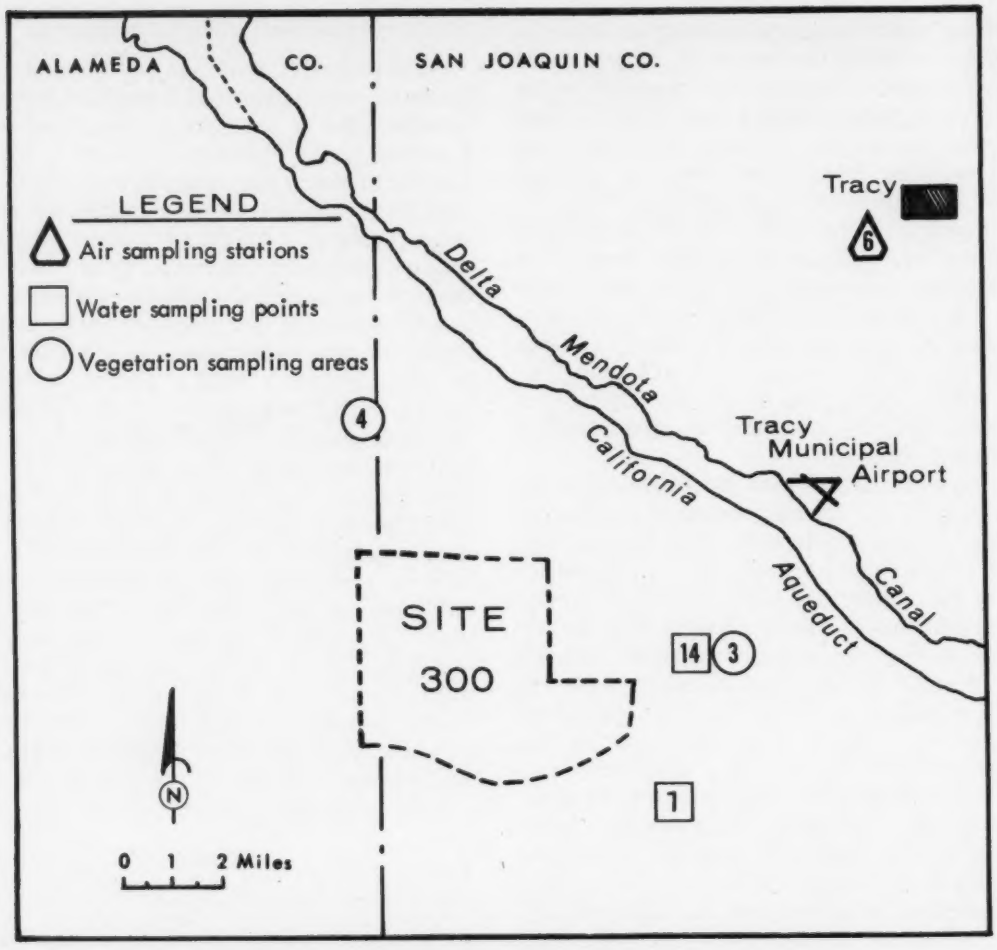

Figure 6. Air, water, and vegetation sampling locations in the Site 300 area (See figure 7 for sampling locations inside Site 300 boundary)

continuously at 11 air sampling locations as shown in figures 6 and 7. Ten of the samplers are located within the boundaries of Site 300, and the 11th is located in Tracy, the primary population center of concern. The onsite samples are collected on 8- by 10-inch Whatman-41 filters at a flow rate of about 25 cfm. Samples in Tracy are collected on 4- by 9-inch HV70 (cellulose-asbestos) filters at a flow rate of about 4 cfm. Filters are changed weekly during the winter months and twice weekly during the summer to avoid excessive mass loading. The filters are analyzed by the method previously described for filters used in the Livermore Valley.

No gross alpha radioactivity above the 1 fCi/m^3 detection limit was observed on these filters. The gross beta activities, averaged over 3-month periods, are listed in table 15 for each sampling location. These average radioactivities are slightly higher than those measured in the Livermore Valley. Gamma spectral measurements made on monthly composite samples of the filters collected onsite reveal measurable quantities of various gamma-emitting radionuclides as may be seen in table 16. These activ-

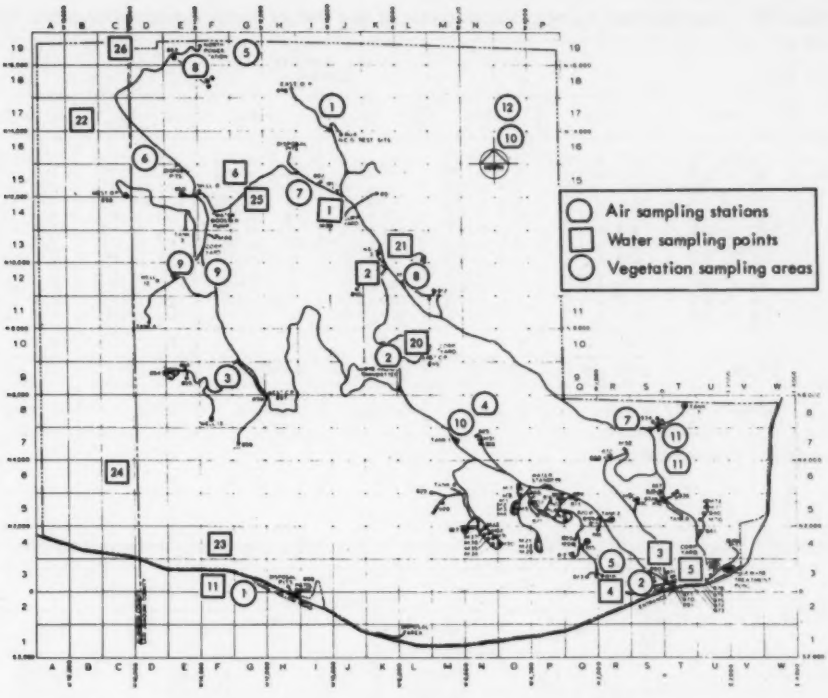

Figure 7. Air, water, and vegetation sampling locations inside Site 300 boundary

Table 15. Airborne particulate activity at Site 300, January–December 1971

Sampling location [a]	Activity concentration (pCi/m³)								Annual average	Percent of AEC standard [b]
	January-March		April-June		July-September		October-December			
	Maximum	Average	Maximum	Average	Maximum	Average	Maximum	Average		
1	0.42 ±1%	0.090	0.33 ±1%	0.26	0.34 ±1%	0.20	0.13 ±6%	0.057	0.15	15
2	.40 ±1%	.095	.34 ±1%	.22	.43 ±1%	.21	.12 ±5%	.054	.14	14
3	.33 ±1%	.086	.29 ±1%	.20	.40 ±1%	.19	.11 ±6%	.051	.13	13
4	.18 ±2%	.065	.30 ±1%	.23	.42 ±1%	.21	.30 ±6%	.079	.15	15
5	.43 ±1%	.090	.27 ±1%	.20	.60 ±2%	.19	.075 ±7%	.041	.13	13
6	.42 ±2%	.12	.31 ±2%	.23	.40 ±2%	.16	.12 ±8%	.065	.14	14
7	.38 ±1%	.089	.32 ±1%	.21	.41 ±1%	.19	.082 ±6%	.046	.13	13
8	.27 ±1%	.077	.29 ±1%	.24	.49 ±1%	.27	.20 ±7%	.12	.18	18
9	.65 ±1%	.13	.45 ±1%	.33	.82 ±1%	.28	.14 ±4%	.061	.20	20
10	.44 ±1%	.11	.39 ±1%	.29	.46 ±1%	.23	.13 ±5%	.099	.18	18
11	.28 ±1%	.10	.61 ±1%	.37	.83 ±1%	.28	.12 ±7%	.059	.20	20

[a] See figure 3.
[b] The AEC standard is 1 pCi/m³.

ity levels are essentially identical with those measured in the Livermore Valley and may readily be accounted for as being due to global fallout. The results of isotopic plutonium and uranium analyses, performed by the techniques described previously, are provided in table 17. The relative abundance of plutonium-238 to plutonium-239 is approximately that expected in global fallout. The uranium content of airborne debris, on the other hand, is appreciably depleted in uranium-235 relative to that of natural uranium and the concentrations of ura-

Table 16. Results of gamma-ray measurements of Site 300 air filters, January–December 1971

Month (1971)	Concentration (fCi/m³)							
	^{144}Ce	^{141}Ce	^{125}Sb	^{7}Be	^{103}Ru	^{106}Ru	^{137}Cs	^{95}Zr
January	8.8± 2%	2.0 ± 7%	0.64±12%	41±3%	2.2 ± 7%	4.0±12%	0.97±5%	2.8±8%
February	15 ± 2%	4.6 ± 4%	1.1 ±14%	47±4%	6.4 ± 4%	4.4±19%	1.4 ±7%	7.4±2%
March	47 ± 1%	18 ± 2%	2.6 ±10%	89±3%	26 ± 2%	18 ± 8%	3.9 ±4%	33 ±1%
April	46 ± 1%	11 ± 2%	2.2 ± 2%	61±4%	19 ± 3%	9.5±10%	3.3 ±6%	33 ±1%
May	120 ± 1%	16 ± 7%	6.8 ± 7%	120±3%	33 ± 2%	50 ± 5%	8.8 ±3%	7.1±1%
June	87 ±13%	9.4 ± 3%	4.7 ±13%	70±5%	18 ± 3%	40 ± 9%	5.6 ±6%	47 ±1%
July	140 ± 1%	8.1 ± 7%	8.1 ± 5%	200±3%	19 ± 4%	59 ± 4%	9.7 ±3%	64 ±1%
August	91 ± 1%	2.9 ± 9%	5.4 ± 7%	150±2%	6.4 ± 6%	40 ± 6%	6.7 ±4%	31 ±1%
September	59 ± 1%	1.9 ±15%	3.4 ±10%	200±2%	3.5 ±10%	29 ± 7%	4.7 ±5%	15 ±2%
October	26 ± 2%	.75±30%	1.4 ±22%	150±3%	1.0 ±25%	9.4± 9%	1.9 ±9%	5.0±4%
November	34 ± 2%	.27±76%	2.4 ±17%	220±2%	.64±39%	13 ±16%	2.8 ±8%	5.6±4%
December	18 ± 3%	16 ± 2%	1.8 ±16%	130±3%	21 ± 2%	10 ±16%	1.8 ±8%	2.8±5%
Annual average	58	7.6	3.3	120	13	24	4.3	21
RCG [a]	200,000	5,000,000	900,000	40,000,000	3,000,000	200,000	500,000	1,000,000
Percent of AEC standard	0.029	0.00015	0.00037	0.00030	0.00043	0.012	0.00086	0.0021

[a] Assumes the activity is in an insoluble form.

Table 17. Plutonium and uranium concentrations in Site 300 air samples, January–December 1971

Month (1971)	Activity (aCi/m³)		$^{241}Pu/^{239}Pu$	Mass (pg/m³)		$^{235}U/^{238}U$
	^{238}Pu	^{239}Pu		^{235}U	^{238}U	
January	3.5 ± 6%	27±3%	0.13	1.8 ±2%	9,300±2%	0.00020
February	3.8 ± 6%	31±3%	.12	.15 ±2%	54±2%	.0028
March	8.2 ± 7%	95±4%	.086	.34 ±1%	83±1%	.0041
April	4.8 ± 6%	67±4%	.072	1.9 ±1%	900±1%	.0021
May	4.5 ± 7%	74±4%	.061	.25 ±4%	65±4%	.0038
June	4.4 ±10%	83±5%	.053	.41 ±2%	180±2%	.0023
July	3.1 ±10%	110±3%	.028	.72 ±2%	250±2%	.0029
August	1.6 ±15%	70±6%	.023	.39 ±1%	98±2%	.0040
September	2.8 ± 6%	54±3%	.052	.27 ±1%	49±1%	.0055
October	1.2 ±12%	35±4%	.034	.31 ±1%	80±1%	.0038
November	1.9 ± 6%	26±3%	.073	.28 ±1%	44±2%	.0064
December	.82± 9%	14±4%	.058	.096±1%	27±2%	.0036
Annual average	3.4	57		.58	930	
AEC standard [a]	1,000,000	1,000,000		1,900,000	15,000,000	
Percent AEC standard	0.00034	0.0057		0.000031	0.0062	

[a] Assumes the activity is in an insoluble form.

nium are at times significantly greater than those measured in the Livermore Valley. This is not unexpected in view of the sizeable quantities of depleted uranium that have been expended over the years as a result of the high explosive detonations at the site. However, these concentrations are nevertheless far lower than the current concentration guide levels.

The calculated annual lung doses to an adult resulting from inhalation of the radionuclides listed in tables 16 and 17 are shown in table 18. These were derived in a manner similar to that used to obtain the values in table 4. Again, these inhalation doses are extremely small with the greatest contribution being due to cerium-144.

Table 18. Inhalation doses resulting from the air concentrations shown in tables 16 and 17

Radionuclide	Calculated annual lung dose (mrem)
Cerium-144	2.4
Cerium-141	.050
Antimony-125	.032
Beryllium-7	.076
Ruthenium-103	.13
Ruthenium-106	.40
Cesium-137	.068
Zirconium-95	.44
Plutonium-238	.0074
Plutonium-239	.12
Uranium-235	.0024
Uranium-238	.56

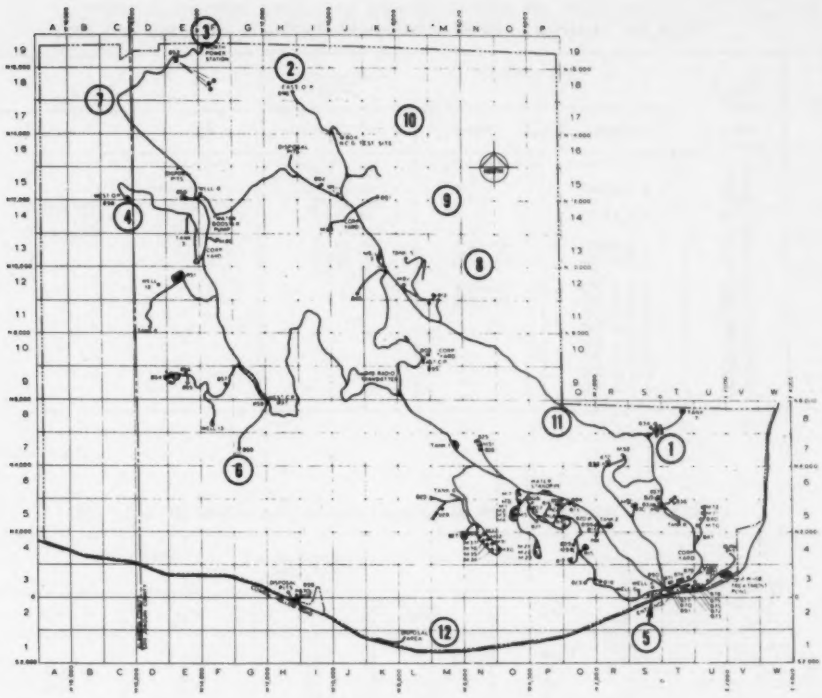

Figure 8. Site 300 soil sampling locations

Soil

A limited number of soil samples were collected at several locations near the site boundary. These locations are shown in figure 8. The samples were collected and analyzed by the same techniques as those collected within the Livermore Valley. The concentrations of the various radionuclides of interest are given in table 19 and the resulting deposition levels are shown in table 20. Inspection of the data reveals that the activities of the artificially produced radionuclides may readily be accounted for as due to global fallout with no detectable contamination as a result of laboratory operations. The data in table 21, however, indicates that the uranium-235 to uranium-238 ratios are slightly depleted in uranium-235 with respect to those observed within the Livermore Valley. This may possibly be due to the depleted uranium being expended in the high explosive detonations at the site, although more data will be required to definitely ascertain this relationship.

Water

Monthly samples were collected from onsite wells supplying Site 300 and from various onsite and offsite springs, ponds, and creeks. The locations of these sites are shown in figure 7. Locations 1 through 7 represent deep-well sources, locations 11 and 14 are offsite creek sources, and rain water is collected at location 20. The remaining locations are onsite ponds or springs. The samples were subjected to gross alpha and beta analyses. No samples showed a gross alpha activity above the limit of detection of 1.2 pCi/liter. The gross beta activities averaged over 3-month periods are given in table 22. These activities show little variation with time and location and are similar to those exhibited by the water samples collected within the Livermore Valley.

These samples were also subjected to tritium analyses by electrolytic enrichment and subsequent scintillation counting. The results of the analyses are shown in table 23. With the ex-

Table 19. Activity levels of various radionuclides in soil at Site 300, 1971

Sampling location	Depth (cm)	Concentration (fCi/g)					Potassium-40 concentration (pCi/g)
		^{239}Pu	^{90}Sr	^{137}Cs	^{95}Zr	^{144}Ce	
1	0–1			370± 8%			4.6±11%
	0–24	3.3± 5%		61±32%			2.7±19%
2	0–1			530± 6%	120±26%	280±38%	4.7±11%
	0–24	2.6±10%		94±19%			1.5± 3%
3	0–1			360± 7%	62±36%	230±40%	5.6± 9%
	0–24	1.3±10%	47±4%	50±31%			4.3±11%
4	0–24	2.3±10%	51±6%	100±17%			
5	0–1			560± 7%			
	0–24	5.3± 5%	62±5%				
6	0–24	2.5± 5%	66±6%				
7	0–25	2.7± 6%					
8	0–25	1.7± 6%					
9	0–25	1.7± 5%					
10	0–25	6.6± 4%					
11	0–25	2.0± 5%					
12	0–25	3.1± 6%					

Table 20. Deposition levels of various radionuclides in Site 300 soils, 1971

Sampling location	Concentration (mCi/km^2)				
	^{239}Pu	^{90}Sr	^{137}Cs	^{95}Zr	^{144}Ce
1	0.89		14		
2	.78		25	1.5	3.5
3	.48	13	12	0.78	2.9
4	.72	15	25		
5	1.7	19			
6	.81	22			
7	.93				
8	.68				
9	.56				
10	2.3				
11	.74				
12	1.2				

Table 21. Concentrations of uranium in Site 300 soils, 1971

Sampling location	Depth (cm)	^{234}U (pg/g)	^{235}U (ng/g)	^{238}U (μg/g)	^{235}U/^{238}U [a]
1	0–24	116 ± 2%	18.0 ±1%	2.60±1%	0.0069
2	0–24	115 ±10%	14.6 ±1%	2.10±1%	.0069
3	0–24	119 ±10%	14.0 ±1%	1.99±2%	.0070
4	0–24	71.0±10%	9.04±1%	1.29±2%	.0070
5	0–24	77.3±10%	9.50±1%	1.37±2%	.0069
6	0–24	126 ±10%	15.5 ±1%	2.24±2%	.0069
7	0–25	151 ±10%	17.3 ±1%	2.45±1%	.0071
8	0–25	116 ±12%	15.6 ±1%	2.33±1%	.0067
9	0–25	88.5±11%	11.0 ±1%	1.60±2%	.0069
10	0–25	101 ±12%	14.2 ±1%	2.13±1%	.0067
11	0–25	138 ±10%	15.9 ±1%	2.27±1%	.0070
12	0–25	109 ±11%	13.6 ±1%	2.00±1%	.0068

[a] The ^{235}U to ^{238}U ratio in natural uranium is 0.0072.

ception of samples collected at location 25, these samples contain tritium activities that are comparable with those observed in water samples collected within the Livermore Valley.

The elevated tritium activities observed at location 25 appear to be due to tritium being leached out of contaminated wastes that have been stored at a nearby location. Adjacent to this

Table 22. Average gross beta activities in Site 300 water samples, January–December 1971

Sampling location	Concentration (pCi/liter)			
	January-March	April-June	July-September	October-December
1	5.5	3.0	5.2	2.8
2	11.0	4.2	4.9	6.2
3	8.7	5.5	6.5	7.7
4	5.9	4.8	4.6	4.0
5	4.8	5.9	5.1	5.2
6	6.2	5.1	4.8	4.5
7	4.0	4.2	5.4	5.4
11	8.2	9.7	6.8	6.3
14	4.8	4.1	2.8	4.1
20	—	—	—	15
21	—	—	9.8	9.0
22	—	—	22	—
23	—	—	7.6	7.8
24	—	—	5.3	7.9
25	—	—	2.9	2.8
26	—	—	—	5.5
Average	6.6	5.2	6.7	6.3
Percent of AEC standard *	22	17	22	21

* AEC standard (beta activity) = 30 pCi/liter.

Table 23. Tritium activities in Site 300 water samples, 1971

Location	Concentration (pCi/liter)		Percent of AEC standard	Calculated annual adult whole body radiation dose (μrem)
	Maximum	Average		
1	18 ±50%	16	0.000016	0.64
3	41 ±22%	26	.000026	1.0
4	18 ±50%	16	.000016	.64
6	36 ±25%	31	.000031	1.2
7	150 ±12%	35	.000035	1.4
8	36 ±25%	20	.000020	.80
11	81 ±11%	60	*.0020	2.4
14	36 ±25%	28	*.00093	1.1
22	83 ±13%	60	.000060	2.4
23	33 ±26%	29	.000029	1.2
24	67 ±13%	58	.000058	2.3
25	720,000 ± 2%	580,000	.58	2,300
26	750 ± 4%	740	*.025	30
Average		45,000		1,800

* Offsite AEC standard RCG (HTO) = 3,000,000 pCi/liter.
Onsite AEC standard RCG (HTO) = 100,000,000 pCi/liter.

spring is a deep-water well at location 6 which apparently has not been contaminated.

Table 23 also includes the calculated whole body doses to an adult consuming the water containing the listed tritium concentrations. These doses were derived in a manner similar to that used to compute the values listed in table 10. As one would expect, the doses are insignificant with the exception of location 25 where it would be possible for 23 mrem to be delivered to an individual consuming 1 liter per day from this spring. It is quite unlikely, however, for any individual to drink this water directly, since the water percolates back into the ground a few feet from the spring.

Vegetation

During the last quarter of 1971, vegetation samples were collected on a monthly basis at 7 sampling locations shown in figure 7. Dried monthly composite samples were subjected to gamma spectral analyses yielding the activities of cesium-137, cerium-144, zirconium-95, beryllium-7, and potassium-40. The average activities are shown in table 24. Also shown in the table are the calculated whole body or critical organ doses delivered to an adult by direct ingestion of 400 grams per day of edible vegetation containing 80 percent water and the listed activities. Again the data reveals that

Table 24. Radionuclide activities in Site 300 vegetation samples, 1971

Radionuclide	Average activity (pCi/g)	Calculated annual radiation dose to man via direct ingestion (mrem)	Critical organ
Cesium-137	0.14	0.26	Whole body
Cerium-144	.70	5.6	Lower large intestine
Zirconium-95	.078	.18	Lower large intestine
Beryllium-7	2.1	.11	Lower large intestine
Potassium-40	4.7	6.4	Whole body

potassium-40 and cerium-144 are the major contributors via this pathway.

These samples were also subjected to tritium analyses by freeze drying and subsequent electrolytic enrichment and scintillation counting of the resulting water. The average activities measured at each location are shown in table 25. With the exception of location 6, the activities show remarkably little fluctuation as compared with the results obtained from similar samples collected within the Livermore Valley.

Table 25. Tritium activities in Site 300 vegetation samples, 1971

Sampling location	Average tritium activity (pCi/liter)	Calculated annual adult radiation dose (μrem)
4	600	9.7
5	700	11
6	2,800	45
7	830	13
8	740	12
10	670	11
12	680	11
Average	1,000	16

Location 6 represents a waste disposal area where tritium-contaminated waste is stored. The table also includes the resulting whole body doses delivered to an adult by the tritium activities based upon the models referenced previously. As one would expect these doses are insignificant.

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2. Shippingport Atomic Power Station[3] January–December 1971

Duquesne Light Company
Shippingport, Pa.

The Shippingport Atomic Power Station is located on the south bank of the Ohio River on a 420-acre site. The site is approximately 1 mile from Midland, Pa., 5 miles from East Liverpool, Ohio, about 25 miles west of Pittsburgh, and about 11 miles below the confluence of the Beaver and Ohio Rivers (figure 9). The station is designed to produce electric energy by a conventional central station type turbine-generator unit. The pressurized water reactor consists of a closed system in which water is circulated by pumps over an array of nuclear fuel elements, or core, contained in a reactor vessel to heat exchangers where steam is formed in a separate isolated system.

Radioactive waste handled under the environmental program includes liquid and gaseous effluents released into the Ohio River and atmosphere, respectively. The levels of radioactivity released have been controlled to levels below the ones specified in the AEC standards (10 CFR 20). The releases have also been less than the limits imposed by the Ohio River Valley Water Sanitation Commission (ORSANCO) (*1*) and by the Commonwealth of Pennsylvania (*2*).

Liquid radioactive waste

The liquid radioactive wastes disposed of at Shippingport result mainly from draining the reactor coolant system and cleaning radioactive tools and equipment. The station is equipped with extensive systems to collect and process the waste water and remove most of the radioactivity before the purified water is discharged to the Ohio River.

The principal source of radioactivity in waste water is from trace amounts of corrosion and wear products from the metal surfaces of the reactor plant. These trace quantities are carried through the reactor by the coolant water and subsequently activated. The primary long-lived corrosion and wear product radionuclide is cobalt-60 (half-life of 5.3 years). A number of short-lived radionuclides are produced in the

[3] Summarized from Environmental Monitoring at Major U.S. Atomic Energy Commission Contractor Sites, Shippingport Atomic Power Station, January–December 1971.

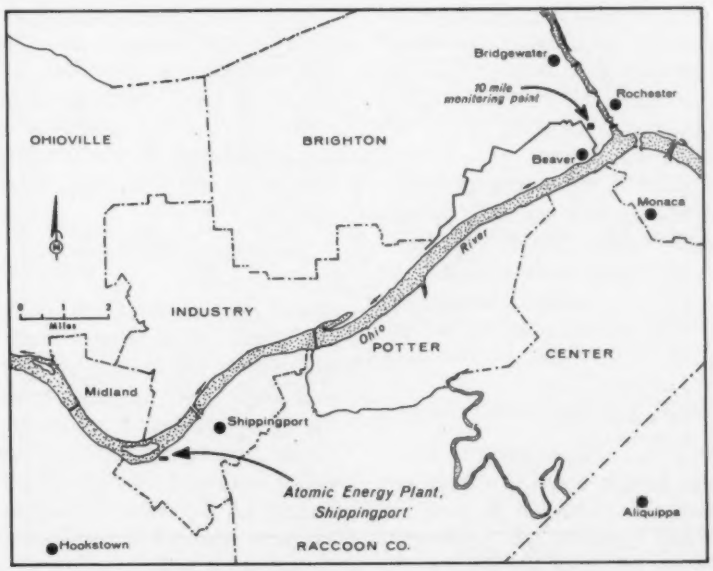

Figure 9. Shippingport Atomic Power Station sampling locations

reactor coolant as well as relatively long-lived tritium (12.3 years). Because of the small initial concentrations and rapid decay, the short-lived radionuclides disappear during holdup of liquid waste in the radioactive waste processing system, leaving the longer-lived tritium and cobalt-60.

During 1971, a total of 46 mCi gross beta-gamma radioactivity in the liquid waste (exclusive of tritium) and 0.66 Ci of tritium were released to the environment. The average releases to the environment for 1971 were 0.79 percent of the AEC standard for total activity (excluding tritium) and 0.016 percent for tritium.

Gaseous radioactive waste

Normal reactor operations produce radionuclides such as noble gases which occur from fission of trace uranium impurities in reactor structures and from irradiation of the water itself. The gases are removed from the primary coolant system periodically and contained for long periods of time to allow radioactive decay and sampling of the gases before their eventual release to the environment.

There were no releases of radioactive gases from the Shippingport radioactive waste system for 1971. In retrospect, the radioactive noble gas releases (primarily xenon-133) for the years 1969 and 1970 were 75 μCi and 19 μCi, respectively. Total airborne and gaseous radioactivity released from Shippingport over its entire operational history since December 1957 has been less than one curie. The annual liquid and gaseous radioactive waste discharges for 1969–1971 are shown in table 26. The discharge points for liquid and gaseous effluent are shown in figure 10.

Table 26. Annual liquid and gaseous radioactive waste discharges, Shippingport Atomic Power Station 1969–1971

Year	Radioactive liquid wastes released to the Ohio River		Gaseous wastes released to the environment (μCi)
	Total activity (excluding tritium) (mCi)	Tritium activity (Ci)	
1969	210	20.1	75
1970	71	1.71	19
1971	46	.66	• 0

• No gases were released due to adequate holdup capacity.

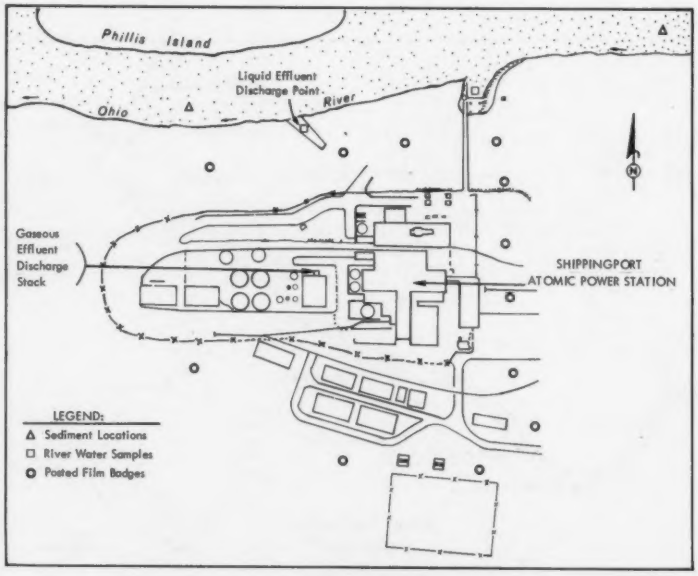

Figure 10. Shippingport liquid and gaseous effluent discharge points

Table 27. Gross radioactivity in the Ohio River, Shippingport Atomic Power Station, January–December 1971

Type of radioactive material	Number of samples	Average concentration (pCi/liter)									
		Upstream				Range Jan–Dec	Downstream				Range Jan–Dec
		Jan–Mar	Apr–June	July–Sept	Oct–Dec		Jan–Mar	Apr–June	July–Sept	Oct–Dec	
Alpha:[a]											
Total solids	13	1.4	1.7	1.0	1.5	0.2– 5.9	1.3	0.8	1.4	1.6	0.3– 5.2
Beta:[b]											
Total solids	13	9.0	13.3	13.7	9.7	2.7–35.1	8.9	12.5	12.8	10.2	2.9–38.0
Potassium-40 [c]	13	4.4	5.0	7.2	6.7	2.9– 8.6	4.5	5.0	7.2	6.7	3.2– 8.6

[a] The 90-percent confidence level of average alpha radioactivity determinations is 0.2 pCi/liter.
[b] The 90-percent confidence level for average beta-gamma radioactivity determination is 0.7 pCi/liter.
[c] The 90-percent confidence level for average potassium-40 radioactivity determination is 0.4 pCi/liter.

Environmental monitoring

Environmental monitoring surveys adjacent to the Shippingport plant have been performed since before initial startup in 1957 and a continuous environmental monitoring program has been carried out during its 14 years of operation to assure the adequacy of waste discharge procedures and limits and to monitor radiation exposure outside the station. This exposure to the general public has not been greater than that received from natural background radiation. These surveys have been reviewed by both the AEC and independently by the Bettis Atomic Power Laboratory. Water from both upstream and downstream sampling points in the Ohio River has been sampled continuously and analyzed weekly, sediment samples from the river have been taken quarterly from upstream and downstream sampling points, and film badges around the boundary of the station and from a 10-mile distant control point have been evaluated monthly.

Ohio River water analysis

During 1971, weekly composite samples were analyzed from two continuous automatic samplers in the station circulating water line upstream and downstream of the radioactive waste effluent release point. These samples were analyzed for gross alpha and beta-gamma radioactivity on both suspended and dissolved solids and also for potassium-40 content. As shown in table 27, no significant difference was observed among the average alpha, beta-gamma and potassium-40 radioactivities for the influent and effluent samples taken from the river during 1971.

Ohio River sediment analysis

The Ohio River bottom silt in the vicinity of Shippingport is sampled quarterly upstream and downstream of the plant outflow. During the years of plant operation, and even before plant operations began in 1957, measurements of sediment have shown a wide variation in radioactivity—both upstream and downstream —caused by uranium, thorium and daughter products of radium which occur naturally throughout the Ohio River Basin and are washed into the river. Over the years 1967 through 1971 the radioactivity in silt samples taken upstream from Shippingport (thus reflecting natural radioactivity) varied between 2.5 and 17.0 pCi/g, with an average value of 8.2 pCi/g. This wide variation was also exhibited in the downstream silt measurements, which have an average value of 9.0 pCi/g. Consistent with the results of previous years, there is no significant difference between the 1971 upstream and downstream sediment sample activities. Shippingport Atomic Power Station discharges have had no significant effect on the radioactivity levels of the river sediment.

Environmental gamma radiation

Twelve film badges for detecting beta-gamma radioactivity were posted monthly throughout the year at the site perimeter in an attempt to determine the external radiation exposure in the immediate area. To determine the normal background levels of radiation in the vicinity

of the station, a control film badge location was established at a point 10 miles from the station boundary in Bridgewater, Pa.

For 1971, the densities of the site perimeter monitoring films were not measurably different from the control film density. This indicates that the radiation exposure to the general public outside the station was not above that received from natural background radiation.

Conclusions

The radioactive discharges processed from the Shippingport Atomic Power Station have not accumulated or concentrated radioactive wastes in the environs surrounding the station. All discharges of radioactive waste materials have been carried out in strict compliance with existing Federal, regional, and State of Pennsylvania regulations. The overall trend in quantities of radioactive waste effluents released to the environs in recent years has steadily decreased.

REFERENCES

(*1*) ORSANCO. Pollution Control Standard 1-70 and 2-70, Ohio River Valley Water Sanitation Commission (ORSANCO), 414 Walnut Street, Cincinnati, Ohio 45202.
(*2*) COMMONWEALTH OF PENNSYLVANIA DEPARTMENT OF HEALTH. Sanitary Water Board, Industrial Wastes Permit No. 1832.

Recent coverage in *Radiation Data and Reports:*

Period	Issue
January–December 1970	November 1972

Reported Nuclear Detonations, September 1973

(Includes seismic signals presumably from foreign nuclear detonations)

Seismic signals from a Soviet underground nuclear explosion in the yield range of 3 to 6 megatons were recorded by the United States on September 12, 1973. The signals originated at approximately 3:00 a.m. (EDT) at the Novaya Zemlya nuclear test area in the Arctic. This test had about the same yield as the one of October 14, 1970, which was the largest Soviet underground test detected by the United States.

Seismic signals, presumably from a Soviet underground nuclear explosion, were recorded by the United States. The signals originated at approximately 11 p.m. (EDT) September 18, 1973, in the central Kazakh Desert and were equivalent to those of an underground nuclear explosion in the yield range of 20 to 200 kilotons.

On September 27, 1973, seismic signals, presumably from a Soviet underground nuclear explosion, were recorded by the United States at approximately 3 a.m. (EDT). The signals originated in Southern Novaya Zemlya in the Arctic and were equivalent to those of an underground nuclear explosion in the yield range of 20 to 200 kilotons.

The U.S. Atomic Energy Commission announced that the United States had recorded seismic signals, presumably from a Soviet underground nuclear explosion on September 30, 1973. The signals originated from the southern Ural area and were equivalent to those of an underground nuclear explosion in the yield range of 20 to 200 kilotons.

There were no reported nuclear detonations for the United States for September 1973.

Not all of the nuclear detonations in the United States are announced immediately, therefore, the information in this section may not be complete. A complete list of announced U.S. nuclear detonations may be obtained upon request from the Division of Public Information, U.S. Atomic Energy Commission, Washington, D.C. 20545.

SYNOPSES

Synopses of reports, incorporating a list of key words, are furnished below in reference card format for the convenience of readers who may wish to clip them for their files.

A HISTORY AND PRELIMINARY INVENTORY REPORT ON THE KENTUCKY RADIOACTIVE WASTE DISPOSAL SITE. *David T. Clark. Radiation Data and Reports, Vol. 14, October 1973,* pp. 573–585.

The Kentucky radioactive waste disposal site, operated by the Nuclear Engineering Company, Incorporated, has been in operation since March 1963. As of January 1, 1972, approximately 0.71 million cubic meters of waste, containing 1,153,333 curies of byproduct material, 208,903 grams of special nuclear material, and 39,493 kilograms of source material, have been disposed of at this facility. Due to the relatively long period of operation and the large quantities of radioactive material involved, a detailed inventory of two of the largest pits at the site was made, based on available disposal records. This report contains a brief history of this facility and a summary of the inventory results.

KEYWORDS: Disposal, Kentucky, liquids, radioactive waste, solids, storage.

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